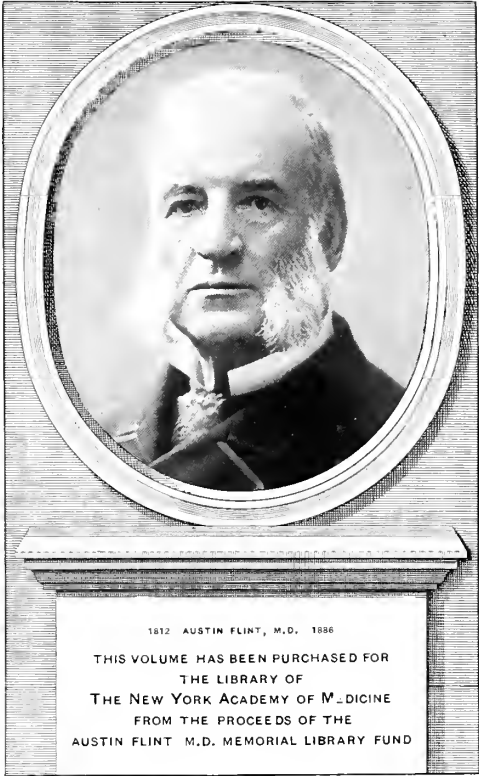




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PHARMACEUTICAL BOTANY

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YOUNGKEN



*Dryopteris marginalis*, one of the ferns whose rhizome and stipes constitute the drug, *Aspidium*.

(Frontispiece)

# PHARMACEUTICAL BOTANY

BY

HEBER. W. YOUNGKEN, PH. G., A. M., M. S., PH. D.

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PHIA, BOTANICAL SOCIETY OF AMERICA, BOTANICAL  
SOCIETY OF PENNSYLVANIA, AMERICAN ASSO-  
CIATION FOR THE ADVANCEMENT OF  
SCIENCE, ETC.

SECOND EDITION, REVISED AND ENLARGED  
WITH 195 ILLUSTRATIONS

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## PREFACE TO THE SECOND EDITION

The appearance of the United States Pharmacopœia IX and the National Formulary IV, with the many changes in the lists and definitions of officially recognized vegetable drugs made it necessary to revise the former edition of this work.

In the course of revision, the writer has taken cognizance of the growing importance of Botany in the curricula of pharmaceutical institutions and has accordingly expanded upon the subject matter of the former text.

With the adoption for the first time by the new United States Pharmacopœia of pharmacognic standards for numerous drugs, Pharmacognosy has risen to the forefront in this country as a science. While its proper comprehension requires laboratory instruction in chemistry, physics, and crystallography as well as botany, nevertheless a rather extended foundation in structural botany stands out preëminently as the most needed requirement.

The work has been for the most part remodeled. Chapter I deals with Fundamental Considerations. Chapter II is devoted to the life history of the Male Fern, a median type of plant, the consideration of which, after the students have received fundamental practice in the use of the microscope, the writer has found commendable, for it not only gives the beginner a working knowledge of structures and functions, the homologies and analogies of which will be met in the later study of forms of higher and lower domain, but holds their interest on account of its economic importance.

The life history of a type of Gymnosperm, White Pine, is next taken up in Chapter III. Chapter IV considers the life history of an Angiosperm as well as coördinates the resemblances and differences between Gymnosperms and Angiosperms. Chapters V, VI and VII are devoted respectively to Vegetable Cytology, Plant Tissues and Plant Organs and Organisms. Among the many additions to the topics included in these might be mentioned a treatise on Cell Formation and Reproduction including Indirect Nuclear Division,

twenty pages on Non-Protoplasmic Cell Contents, the consideration of Woods, Root Tubercles, the gross structure and histology of different types of leaves, broad histologic differences between Monocotyl and Dicotyl leaves, the histology of floral parts and the histology of types of fruits and seeds. Chapter VIII on Taxonomy has been increased by the addition of 144 pages. Several new families of drug-yielding plants have been added and the treatment of family characteristics has in the majority of instances been broadened. The habitats of drug-yielding plants have been added. In that portion of the tables dealing with the names of official drugs, those official in the National Formulary have been so designated by the abbreviation N. F., to distinguish them from others that may occur in the same portion of the table and which are official in the Pharmacopœia.

In keeping with the increased size of the book, many new illustrations have been introduced. A number of these are original drawings, photographs and photomicrographs. To the authors of other works from which cuts were borrowed, the writer's thanks are due.

The writer in conclusion desires to thank Dr. John M. Macfarlane, head of the Botanical Department of the University of Pennsylvania, for valuable suggestions during the preparation of portions of the text.

H. W. Y.

## PREFACE TO THE FIRST EDITION

The aim has been to eliminate from this book all those topics that are of minor importance to the student and practitioner of Pharmacy. As a pharmacist and teacher, the writer feels that the botanical preparation for Pharmacognosy and Materia Medica, in those colleges where Botany is given for one year, should include mainly the structural and systematic aspects of the science. In the Medico-Chirurgical College, of Philadelphia, Botany is taught the first year, extending over a period of 155 hours. The author has introduced in this concise volume the important subject matter of his lectures given to first year students, and has omitted laboratory directions for the obvious reason that fixed subjects for laboratory study are unnecessary. It is not a book on Pharmacognosy, however, since it does not describe how one drug differs from another of the same group in all of its details.

The work is included in two parts. Part I is largely devoted to the morphology (gross and minute) and, to a less extent, the physiology of the Angiosperms. Part II deals with the taxonomy of plants, mainly but not wholly of medicinal value, together with the parts used and the names of the official and non-official drugs obtained from these.

The author does not claim sole originality for the facts presented, but has consulted many sources of information, mention of which will be found in the bibliography of the text.

Acknowledgment is here made to his esteemed friends, Dr. Francis E. Stewart of the Medico-Chirurgical College and Dr. John M. Macfarlane of the University of Pennsylvania, for valuable assistance in the reading of the proofs and preparation of the index.

H. W. Y.

PHILADELPHIA.



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# PHARMACEUTICAL BOTANY

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## CHAPTER I

### [FUNDAMENTAL CONSIDERATIONS

### [Botany is the Science which Treats of Plants

#### DEPARTMENTS OF BOTANICAL INQUIRY

1. **Morphology** treats of the parts, or structures of plants. It is divided into:

(a) **Macromorphology** or **Gross Anatomy** which deals with the external characters of plants or their parts; (b) **Micromorphology** or **Histology** which considers the minute or microscopical structure of plants and plant tissues; and (c) **Cytology** which treats of plant cells and their contents.

2. **Physiology** deals with the study of the life processes or functions of plants. It explains how the various parts of plants perform their work of growth, reproduction, and the preparation of food for the support of animal life from substances not adapted to that use.

3. **Taxonomy** or **Systematic Botany** considers the classification or arrangement of plants in groups or ranks in accordance with their relationships to one another.

4. **Ecology** treats of plants and their parts in relation to their environment.

5. **Phytopathology** treats of diseases of plants.

6. **Phytogeography** or **Plant Geography** treats of the distribution of plants upon the earth. The center of distribution for each species of plant is the *habitat* or the original source from which it spreads, often over widely distant regions. When plants grow in their native countries they are said to be *indigenous* to those regions.

When they grow in a locality other than their original home they are said to be *naturalized*.

7. **Phytopalæontology** or **Geological Botany** treats of plants of former ages of the earth's history traceable in their fossil remains.

8. **Etiology** is the study of the causes of various phenomena exhibited by plants.

9. **Economic or Applied Botany** deals with the science from a practical standpoint, showing the special adaptation of the vegetable kingdom to the needs of everyday life. It comprises a number of subdivisions, viz.: **Agricultural Botany**, **Horticulture**, **Forestry**, **Plant Breeding**, and **Pharmaceutical Botany**. **Pharmaceutical Botany** considers plants or their parts with reference to their use as drugs. It interlocks very closely with other departments of botanical science.

### PRINCIPLES OF CLASSIFICATION

The classification of plants is an attempt to express the exact kinship which is believed to exist among them. By grouping together those plants which are in some respects similar and combining these groups with others, it is possible to form something like an orderly system of classification. Such a system based upon natural resemblances is called a **natural system**. In a natural system of classification every individual plant belongs to a *species*, every species to a *genus*, every genus to a *family*, every family to an *order*, every order to a *class*, every class to a *division*. In many instances species may be subdivided into *varieties* or races. The crossing of two varieties or species, rarely of two genera, gives rise to a *hybrid*. Thus, the species *Papaver somniferum* which yields the opium of the Pharmacopœia belongs to the genus *Papaver*, being placed in this genus with other species which have one or more essential characteristics in common. The genera *Papaver*, *Sanguinaria* and *Chelidonium*, while differing from each other in certain essential respects nevertheless agree in other particulars such as having latex, perfect flowers, capsular fruits, etc., and so are placed in the *Papaveraceæ* family. The *Papaveraceæ* family and the *Fumariaceæ* family are closely allied, the latter only differing from the former in having

irregular petals, usually diadelphous stamens and non-oily albumen and so both of these families are placed in the order *Papaverales*. The orders *Papaverales*, *Geraniales*, *Sapindales*, *Rhamnales*, etc., are related by a common structure namely, two seed leaves or cotyledons and so are grouped together under the class *Dicotyledoneæ*. The *Dicotyledoneæ* differ from the *Monocotyledoneæ* in that the latter group possess but one cotyledon; but both classes agree in having covered ovules and seeds, and so are placed in the subdivision *Angiospermæ*. The *Angiospermæ* differ from the *Gymnospermæ* in that the latter possess naked ovules and seeds but both of these subdivisions agree in producing real flowers and seeds. For these reasons they are placed in the division **Spermatophyta** of the Vegetable Kingdom.

#### OUTLINE OF PLANT GROUPS

I. <b>Thallophyta</b>	}	1. <b>Protophyta</b>	{	Bacteria
				Cyanophyceæ
		2. <b>Myxomycetes</b>	{	Acrasiales
				Phytomyxales
				Myxogastrales
		3. <b>Algæ</b>	{	Chlorophyceæ
				Phæophyceæ
				Rhodophyceæ
		4. <b>Fungi</b>	{	Phycomycetes
				Ascomycetes
				Basidiomycetes
				Fungi Imperfecti
		5. <b>Lichenes</b>	{	Crustaceous
				Foliaceous
				Fruticose
II. <b>Bryophyta</b>	}	1. <b>Hepaticæ</b>	{	Marchantiales
				Jungermanniales
				Anthocerotales
				Sphagnales
		2. <b>Musci</b>	{	Andrææales
				Bryales

III. Pteridophyta	$\left\{ \begin{array}{l} 1. \text{ Lycopodineæ} \\ 2. \text{ Equisetineæ} \\ 3. \text{ Filicineæ} \end{array} \right.$	Lycopodiales
		Selaginalles
		Isoetales
IV. Spermatophyta	$\left\{ \begin{array}{l} 1. \text{ Gymnospermæ} \\ 2. \text{ Angiospermæ} \end{array} \right.$	Equisetales
		Ophioglossales
		Filicales
	$\left\{ \begin{array}{l} 1. \text{ Gymnospermæ} \\ 2. \text{ Angiospermæ} \end{array} \right.$	Cycadales
		Ginkgoales
		Coniferales
		Gnetales
$\left\{ \begin{array}{l} 1. \text{ Gymnospermæ} \\ 2. \text{ Angiospermæ} \end{array} \right.$	Monocotyledoneæ	
	Dicotyledoneæ	

### THE MICROSCOPE

A microscope is an optical instrument, consisting of a lens, or combination of lenses, for making an enlarged image of an object which is too minute to be viewed by the naked eye.

Microscopes are of two kinds, viz.: simple and compound.

#### THE SIMPLE MICROSCOPE

This consists simply of a convex lens or several combined into a system and mounted in a suitable stand. A good example of a simple microscope is a reading glass.

#### THE COMPOUND MICROSCOPE

##### A. *Its Construction:*

The principal parts of a compound microscope are:

1. The *base*, generally horseshoe shaped, which rests on the table.
2. The *pillar*, an upright bar, which is attached to the base below and supports the rest of the instrument.
3. The *stage*, a horizontal shelf upon which is placed the preparation or slide to be examined. The stage is perforated in the center for transmitting light reflected up by the mirror. On the stage are two clips for holding the glass slide.
4. The *mirror*, situated below the stage, by which the light is reflected upward through the opening in the stage.



5. The *diaphragm*, inserted in the opening of the stage or attached to its lower face, and used to regulate the amount of light reflected by the mirror.

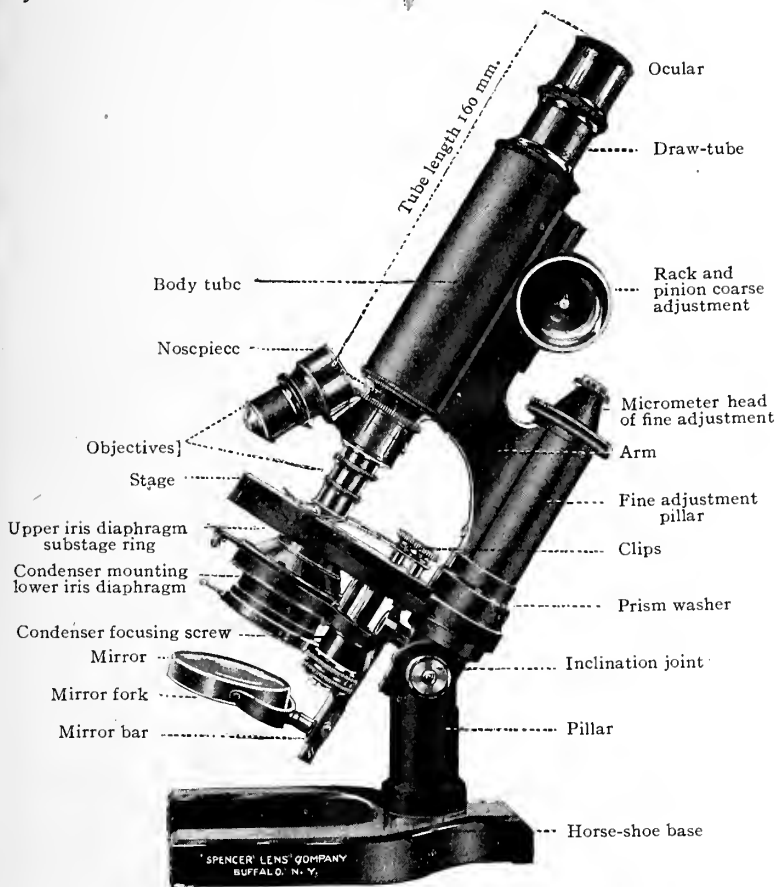


FIG. 1.—Illustrating the parts of a compound microscope.

6. The *body tube*, a cylinder which holds the *draw tube* and *lenses* and moves up and down perpendicularly above the opening in the stage. The tube is raised or lowered either by sliding it back and forth with a twisting movement or by a *rack and pinion* mechanism. The latter is called the *coarse adjustment*.

7. The *fine adjustment*, a micrometer screw back of the tube, which, on being turned, produces a very small motion of the entire framework which holds the body tube.

8. The *oculars* or *eyepieces* which slip into the upper end of the *draw tube*. Each of these consists of two plano-convex lenses, the lower one being the larger and known as the *field lens* because it increases the field of vision. The upper or smaller lens is called the *eye lens*. It magnifies the image formed by the objective. Midway between the field and eye lens is a perforated diaphragm, the object of which is to cut out edge rays from the image.

According to the system adopted by the maker, oculars are designated by numbers, as 1, 2, 3, 4, etc., or by figures which represent focal lengths.

9. The *objectives*, which screw into the bottom of the body tube or nose piece. They consist of a system of two, three or four lenses, some of which are simple, others compounded of a convex crown lens and a concave flint lens. Objectives like oculars are usually designated by numbers or by figures, as  $\frac{1}{12}$ ,  $\frac{1}{6}$ ,  $\frac{2}{3}$ , etc., or in millimeters, which represent focal lengths.

The smaller the number or fraction representing the focal length of an objective, the greater is its magnifying power.

Objectives are either *dry* lenses or *immersion* lenses. If an air space be present between the objective and the object, the lens is called a *dry* one; if a liquid is present between the objective and the object, the lens is called an *immersion* lens. If this liquid be oil the objective is called an *oil immersion objective*; if water, a *water immersion objective*.

Some microscopes are fitted up with a *nose piece*, capable of carrying two or three objectives, which may be revolved into place at the lower end of the body tube. Others have a *condenser* which is employed to concentrate the light upon the object examined.

#### B. *Its Use:*

1. Place the microscope on the table with the pillar nearest you.
2. Screw the objectives into the nose piece and slip an ocular into the upper end, if not already on instrument. Turn the lowest power objective into position.
3. Find the light by looking into the ocular (eye piece) and at the

same time turning the mirror at such an angle that it reflects light from the window or lamp up through the opening in the stage to the objective. Mirrors have two faces, a plane and a concave. Use the concave unless otherwise directed.

4. Regulate the quantity of light by the diaphragm. If too bright it must be cut off somewhat. The higher powers require brighter light than the lower.

5. Place the slide on the stage in a horizontal position with the object over the middle of the opening through which light is thrown from the mirror.

6. With the lower power in position, move the coarse adjustment until either the object or small solid particles on the slide appear distinctly, which means that the lenses are *in focus*. The object, if not under the lens, may now be brought into the field by moving the slide back and forth very slowly while looking through the ocular. To improve the focus, slowly turn the fine adjustment screw.

7. To focus with the high-power objective, first find the object with the low power and arrange in the center of the field. Put clips on slide without moving it. Raise the body tube by means of the coarse adjustment. Then turn the high-power objective into position. (If two objectives only accompany your instrument, the high-power is the longer one.) Lower the body tube carrying the objective until the objective front lens nearly touches the cover glass. A slight movement of the fine adjustment should show the object clearly. Never focus down with the high-power objective because of the danger of pressing it into the cover glass and ruining the delicately mounted lenses.

8. Accustom yourself to use both eyes indifferently and always keep both eyes open. If right handed, observe with the left eye, as it is more convenient in making drawings.

### RULES FOR THE CARE OF THE MICROSCOPE

1. In carrying the microscope to or from your table, grasp it firmly by the pillar and hold in an erect position, so that the ocular which is fitted loosely into the draw tube may not fall out and its lenses become damaged.

2. Never allow the objective to touch the cover glass or the liquid in which the object is mounted.

3. Note whether the front lens of the objective is clean before attempting to use it. If soiled, breathe on the lens and gently wipe with an old, clean, soft handkerchief or lens paper. If the lens be soiled with balsam or some other sticky substance, moisten the handkerchief or lens paper with a drop of xylol, taking care to wipe it perfectly dry as soon as possible.

4. Do not let the objective remain long near corrosive liquids, such as strong solutions of iodine, corrosive sublimate, or mineral acids. Never examine objects lying in such fluids without putting on a cover glass.

5. Never lift the slide from the stage, but, after raising the objective, slide it off the stage without upward movement.

6. Never allow the *stand* (microscope without lenses) to be wetted with such substances as alcohol, soap, etc., which dissolve lacquer.

7. Keep the microscope covered when not in use.

#### THE TECHNIQUE OF MAKING PERMANENT MOUNTS

1. *The Mounting Medium*.—When a microscopic object is to be preserved permanently it must be kept from decaying and the fluid in which it is placed must be kept from evaporating. These conditions can be met by adding an antiseptic (acetic acid, formaldehyde) to the water used in mounting and carefully sealing the cover glass. As a rule, a better way is to use a mounting medium that will not evaporate, *e.g.*, glycerine or Canada balsam. Both these fluids have a high refractive index and so render the objects penetrated by them more transparent. This quality is generally an advantage, but for objects already almost transparent it is quite the reverse. Glycerine has the disadvantage of always remaining soft, so that the mount may at any time be spoiled by careless handling. Canada balsam, on the other hand, slowly becomes solid, so that the mount is exposed to no accident short of actual breakage. Balsam has the disadvantage of being non-miscible with water, so that before it can be used the object must be carefully dehydrated. Even after this is done, and the object lying in absolute alcohol, an oil must be used as an intermediate agent between alcohol and balsam.

2. *Staining*.—For two reasons it is generally better to stain plant tissues before mounting. Transparent tissues may become almost invisible in glycerine or balsam, and different tissues take a stain differently. This being the case it becomes possible to stain one tissue and not another, or one tissue with one stain and another in the same section with a different stain, so that the different parts may be brought out like areas on a colored map. The most common stains are hæmatoxylin derived from logwood, and various anilin stains—safranin, fuchsin, eosin, iodine green, methyl-green, etc.

#### METHOD FOR THE PREPARATION OF A CANADA BALSAM MOUNT

1. Stain object with 0.5 per cent. solution of safranin in 50 per cent. alcohol for from three to five minutes.
2. Wash out excess of stain and further dehydrate with 70 per cent. alcohol.
3. Stain with 0.5 per cent. solution of methyl-green in 70 per cent. alcohol for twenty seconds or longer, depending upon the nature of the material.
4. Dehydrate and wash out excess of stain with 95 per cent. alcohol for two minutes.
5. Further dehydrate by placing material in absolute alcohol for one minute.
6. Clear in cedar oil.
7. Mount in Canada balsam.
8. Label slide.

#### METHOD FOR THE STAINING AND MOUNTING OF MATERIAL IN PARAFFINE RIBBONS AFFIXED TO SLIDE

1. Gently heat the dry slides with paraffine ribbons adhering to the fixative, high above the Bunsen flame (with the ribbon side up).
2. Place the slide upright in a well of xylol or turpentine. The xylol or turpentine will dissolve the melted paraffine in a minute or two.
3. Take the slide out of the well, wipe off the under side and allow a stream of 95 per cent. alcohol to run over the upper side from a pipette.

4. Place the slide upright in a well of safranin for from four to twenty-four hours.
5. Take the slide out of the safranin well and extract excess of stain with 50 per cent. alcohol.
6. Place the slide in a well of gentian violet or methyl-green for a second or more. The time varies for different objects and can only be determined by trial.
7. Rinse slide with 70 per cent. alcohol from pipette.
8. Pour absolute alcohol over sections, follow with a few drops of clove oil, replace clove oil with cedar oil.
9. Mount in balsam.

### MAKING OF SECTIONS

*Free-hand Sectioning.*—Free-hand sections are usually satisfactory for the general examination of roots, stems, leaves, barks and many fruits and seeds. Material which is fresh may be sectioned at once, but dry material should be well soaked in warm water before using. Very hard material like heartwoods, the shells of nuts and seeds, may be softened in solution of caustic potash or ammonia water and then washed free of alkali before sectioning.

The object to be sectioned is held between the thumb and finger of the left hand, or, if small and of soft texture, it must be placed between two flat pieces of elder pith. The upper surface of the razor is wetted with water or 50 per cent. alcohol. The razor, which should be real sharp, is held in the right hand and is drawn across the object with the edge toward the student and the blade sliding on the forefinger of the left hand. The sections should be cut as thin as possible. As soon as a number of sections have been cut, they can be transferred to a vessel of water with a camel's hair brush.

*Sectioning in Paraffine or Celloidin.*—When it is necessary to study the microscopic structure of very delicate plant parts, the material should be imbedded in paraffine or celloidin, subsequently hardened, and sectioned by means of a sliding or rotary microtome. In your course this work will be carried on by the laboratory staff.

### KINDS OF SECTIONS

1. A *transverse* or *cross-section* is one made horizontally through the object, hence its plane lies at right angles to the long axis.

2. A *radial-longitudinal* section is one which is made parallel to the long axis of the object in such a way that it lies in plane of the radius.

3. A *tangential-longitudinal* section is one made parallel to a plane tangent to the cylinder.

### MICROMETRY

The unit of length used in microscopic measurement is the *micron* ( $\mu$ ) which is one-thousandth part of a millimeter (0.001 mm.) or one twenty-five thousandth part of an inch.

In measuring microscopic objects it is necessary to make use of a micrometer of some kind. That pretty generally used is the *ocular micrometer*. It is a circle of glass suitable for insertion within the ocular with a scale etched on its surface. The scale is divided to tenths of a millimeter (0.1 mm.) or the entire surface of the glass may be etched with squares (0.1 mm.), the net micrometer.

### STANDARDIZATION OF OCULAR MICROMETER

The value of each division of the *ocular micrometer scale* must be ascertained for each optical combination (ocular, objective, and tube length) by the aid of a stage micrometer.

The *stage micrometer* is a slide with a scale engraved on it divided to hundredths of a millimeter (0.01 mm.), in some cases to tenths of a millimeter (0.1 mm.), every tenth line being made longer than intervening ones, to facilitate counting.

#### METHOD:

1. Insert the ocular micrometer within the tube of the ocular by placing it on the diaphragm of the ocular, and adjust the stage micrometer by placing it on the stage of the microscope.

2. Focus the scale of the stage micrometer accurately so that the lines of the two micrometers will appear in the same plane. Make the lines on the two micrometers parallel each other. This can often be done by turning the ocular to the right or left while looking into the microscope.

3. Make two of the lines on the ocular micrometer coincide with two on the stage micrometer. Note the number of included divisions.

4. Note the known value for each division of the stage micrometer scale which may either be etched on the stage micrometer or indicated on a label found pasted upon it. If the value indicated is 0.01 mm. ( $\frac{1}{100}$  mm.) then each division of the stage micrometer scale has a value of 10 microns; if 0.1 mm. ( $\frac{1}{10}$  mm.), 100 microns.

5. Multiply the number of included divisions of the stage micrometer scale by the value in microns given for each division and divide the result by the number of included divisions of the ocular micrometer scale. The quotient represents the value of each division of the ocular micrometer scale.

6. Note the optical combination (number of ocular, objective and tube length) used and keep a record of it with the calculated micrometer value. Repeat for each of the combinations.

To measure an object by this method read off the number of divisions it occupies of the ocular micrometer scale, and express the result in microns by looking up the recorded value for the optical combination used.



## CHAPTER II

### LIFE HISTORY OF THE MALE FERN [DRYOPTERIS (ASPIDIUM OR NEPHRODIUM) FILIX-MAS]

The Male Fern along with the Marginal Fern (*Dryopteris marginalis*) have long been known to the pharmaceutical and medical professions as the source of the drug **Aspidium**, a most valuable remedy for the expulsion of tapeworm. The parts of these plants employed are the rhizome and stipes which are collected in autumn, freed of the roots and dead portions and dried at a temperature not exceeding 70°C.

#### HISTORY OF THE SPOROPHYTE OR ASEXUAL GENERATION

**Gross Structure of Stem.**—The main axis of *Dryopteris Filix-mas* is the creeping underground stem or *rhizome* which is oblique or ascending in habit. It gives off numerous *roots* from its lower and posterior portions and *fronds* from its upper and anterior portions. Behind the fronds of the present year are to be noted the persistent stalk bases of fronds of previous seasons. *Lateral buds* are frequently to be noted connected with these. The roots are slender and brown with semi-transparent apices. They are inserted on the bases of the fronds, close to their junction with the stem. The growing end of the rhizome is called the anterior extremity and is marked by the presence of an *apical bud* overarched by young fronds. The opposite end is known as the posterior extremity and in the living plant is constantly decaying as the anterior portion elongates.

**Histology of Mature Stem.**—Passing from periphery toward the center the following structures are to be observed:

1. **Epidermis**, a protective outer covering tissue, composed of a single layer of brownish polyhedral cells from which are given off scaly hairs.

2. **Outer cortex** (hypodermis), a zone of several layers of thick-walled lignified cells separating the epidermis from the inner cortex beneath. Its main function is to support the epidermis.

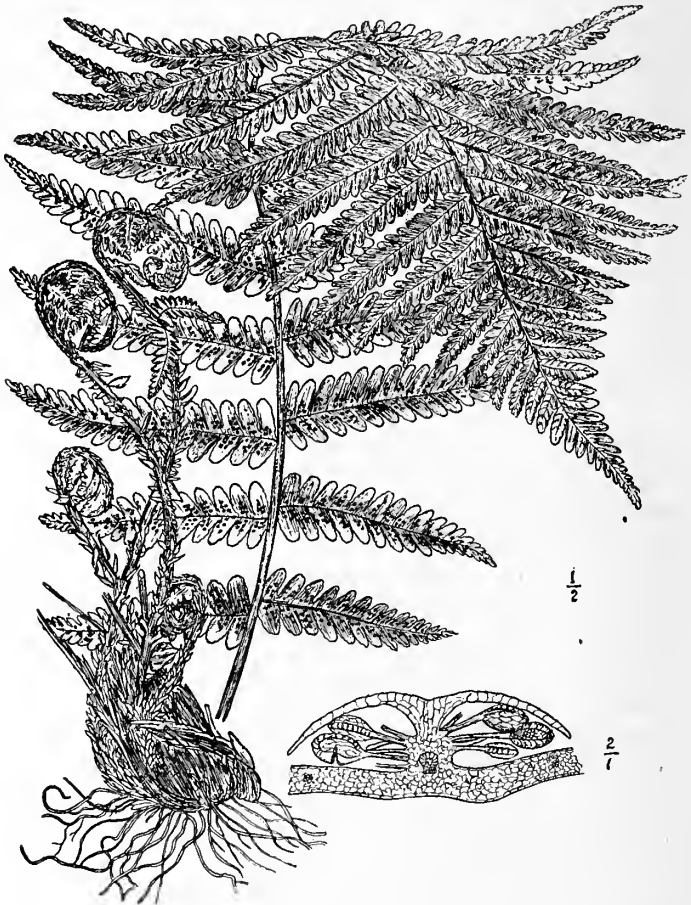


FIG. 2.—*Dryopteris filix-mas*—Plant and section through pinnule and sorus. (Sayre.)

3. **Inner cortex** of several layers of more or less isodiametric cells with thin cellulose walls and containing stored starch surrounded by a protoplasmic investment. These cells conduct sap by osmosis and

store food. Between the cells are to be noted intercellular air spaces, many of which contain internal glandular hairs.

4. **Fundamental tissue**, resembling the last in aspect and function.

5. **Vascular Bundles**.—These are of two kinds, viz.: stem bundles and leaf-trace bundles. Both are of elliptical outline and are embedded in the parenchyma forming the broad central matrix. The stem bundles are comparatively broad and form a continuous network with good-sized meshes, each mesh being opposite the point of insertion of one of the leaves. In transverse section these bundles are seen to be usually ten in number and arranged in an interrupted circle within the fundamental tissue. The leaf-trace bundles are comparatively narrow and are observed to come off of the stem-bundles and pass out through the cortex into the leaves (fronds). When each bundle is examined under a high-power magnification it is seen to be composed of: (a) an *endodermis* or *bundle sheath*, a single layer of cells with yellowish walls and granular contents; (b) a *pericambium* or phloem sheath of one to three layers of delicate thin-walled cells, rich in protoplasm; (c) a *phloem*, a broad zone of tissue formed of *phloem* cells, with thin cellulose walls and protoplasmic contents, which convey sugar in solution from the leaves to the roots and broader *sieve tubes* which appear polygonal in transverse section and whose function is that of conveying soluble proteins in the same direction; (d) a *xylem* (wood) formed of thin-walled *xylem cells* which store food and *scalariform tubes* or *tracheids* which conduct crude sap (water with mineral salts in solution) from the roots to the leaves (fronds). Since the xylem is surrounded by the phloem, the fibro-vascular bundle is of the *concentric* type. Strictly speaking the endodermis and pericambium are accessory regions surrounding, but not part of the bundle proper.

**Histology of Growing Apex**.—When the bases of the leaves of the current year, the circinate leaves of the following year and the large mass of brown scales have been removed from around the apical bud of a well-grown plant, the following structures may readily be observed with a hand lens:

1. The **apical cone** (*punctum vegetationis*), a rounded papilla, which occupies a terminal position in the apical region.

2. The **young fronds**, arranged around the apical cone.

Upon removing the extreme apex of the apical cone with a sharp razor, mounting in dilute glycerine or water and examining under low power, it will be noted that a large pyramidal cell occupies the center of the apical cone. This is the *apical cell*. The cells surrounding it have been derived by segmentation (cell-division) from it, by means of walls parallel to its three sides; they are termed *segment cells* and in turn undergo further division and redivision to originate the entire stem tissue and leaf tissue. Step by step the tissue cells become modified into epidermal, cortical, bundle and fundamental cells.

**Histology of Mature Root.**—Transverse sections cut some distance above the apex will present the following structures for examination:

1. **Epidermis**, of epidermal cells whose outer walls are brown. Some of these cells have grown out as root hairs which surround soil particles and absorb water with mineral salts in solution.

2. **Cortex**, of many layers of cortical parenchyme cells with brown walls. The outer layers of cells of this region are thin-walled while the extreme inner ones are lignified and form a sclerenchymatous ring which surrounds the

3. **Endodermis**, a single layer of cells tangentially elongated.

4. **Pericambium** (Pericycle), usually of two layers of thin-walled cells containing protoplasm and large nuclei. This region surrounds the

5. **Radial fibro-vascular bundle**, consisting of two phloem patches of phloem cells and sieve tubes on either side of two radial xylem arms of xylem cells, spiral tracheæ and scalariform tubes.

6. **Lateral rootlets** which take origin in the pericambium.

**Histology of Root Apex.**—Microscopic examination shows this region to be composed of soft, pale, growing cells ending in the triangular *apex-cell* of the root. From the free base of the apex cell *segment cells* are cut off as *calyptragen* cells. These by dividing form the *root cap*. The root cap or *calyptra* consists of a mass of loosely attached cells which forms a protective covering around the tip of the root.

From the inner sloping sides of the apex cell the segment cells give origin to the *dermatogen*, which by repeated division of its cells originates the *epidermis* (outer protective covering of the root), the *peri-*

blem, originating *cortex*, and the *plerome* originating the *bundle* and *related tissue*.

**Continuity of Crude Sap Flow.**—The *crude sap* (water with mineral salts in solution) penetrates the thin walls of the root hairs by osmosis and passes into the interior of hairs, thence into the root xylem and through this to stem xylem, thence through stem xylem into the leaves.

**Histology of Stipe (Petiole).**—This in transverse section passing from periphery toward the center presents the following structural characteristics:

1. **Epidermis**, a single layer of epidermal cells with dark brown outer walls.

2. **Outer cortex** (hypodermis), a wide band of small cells with lignified walls.

3. **Inner cortex**, similar to inner cortex of stem but devoid of leaf-trace bundle.

4. **Fundamental parenchyma**, similar to same region of stem in which are embedded a number of *concentric fibro-vascular bundles* arranged in an interrupted circle. Each of these shows a central xylem mass surrounded by an outer phloem mass. Each bundle is enveloped by a *pericambium* and an *endodermis* or bundle sheath.

**Histology of Lamina.**—In transverse and surface sections the *lamina* or blade shows the following structural details:

1. **Upper epidermis** of wavy-walled, slightly chlorophylloid, flat upper epidermal cells devoid of stomata but with rather thick cuticle.

2. **Mesophyll** of irregular shaped chlorophylloid cells containing abundant chloroplasts. Intercellular-air-spaces are found between various cells which are larger in the lower than the upper region. Internal glandular hairs are frequently to be discerned in many of these spaces.

3. **Concentric vascular bundles** or laminar veins that distribute sap to, and carry sap from the mesophyll. These are seen to be embedded in the mesophyll. The xylem portion of each bundle is nearest to the upper surface of the leaf and so the bundles approach the collateral type.

4. **Endodermis**, a continuous layer of mesophyll cells which surrounds each bundle and binds it in place.

5. **Lower epidermis** of wavy-walled, flattened, chlorophylloid cells with thin cuticle and many *stomata* (breathing pores). Each **stoma** is surrounded by a pair of crescent-shaped *guard cells* which regulate its opening and closing. The upper and lower epidermis are continuous around the laminar margin.

**Comparative Physiology of Root, Stem and Leaf (Frond).**—The primary function of the roots of the Male Fern is that of absorption of water with mineral salts in solution. The secondary function is that of support for the stem, the tertiary, that of storing food-stuffs to tide the plant over the season when vegetative activities are lessened. Water is the most essential of all materials absorbed by vegetable organisms. It is found in the soil surrounding the soil particles with certain mineral salts dissolved in it. The delicate root-hairs with thin cellulose walls, protoplasmic lining and sap denser than the soil water, are firmly adherent to these particles. The soil water diffuses through these walls by osmosis and comes into relation with the *ectoplasm*, a delicate protoplasmic membrane which has the power of selecting what it wants and rejecting what it does not need. In this way only such solutes as are of value to the plant are admitted. The water with mineral salts in solution, once within the root-hair protoplast, is called "crude sap." This passes through the hair into the cortical parenchyma cells which are in contact with the spiral ducts and scalariform tracheids. It passes from one cortex cell to another by osmosis and, under considerable root pressure, is forced into the spiral and scalariform tubes of the xylem. Therein it is conveyed upward by root pressure through the tracheids of the stem bundles into those of the leaves and finally osmose into the leaf parenchyma cells (mesophyll).

Carbon dioxide, ( $\text{CO}_2$ ), from the air enters the leaf through the stomata. From the stomata it moves through the intercellular air spaces to the mesophyll cells which line these, whence it is absorbed. Within the mesophyll cells are found small chloroplasts composed of protoplasm and chlorophyll. The kinetic energy of the sun's rays is absorbed by the chlorophyll which is thus energized to break up the  $\text{CO}_2$  and  $\text{H}_2\text{O}$  into their component elements C, H and O, and rearrange them in such a way as to ultimately form sugar or starch. This process is called *photosynthesis*. According to von Baeyer,

CO<sub>2</sub> is split into C and O<sub>2</sub>, the C being retained, the O<sub>2</sub> given off. The nascent C is linked with H<sub>2</sub>O to form CH<sub>2</sub>O (formic-aldehyde); six molecules of this are then united to form grape sugar (C<sub>6</sub>H<sub>12</sub>O<sub>6</sub>). The formation of starch may be expressed by the following equation:  $6\text{CO}_2 + 5\text{H}_2\text{O} = \text{C}_6\text{H}_{10}\text{O}_5 + 6\text{O}_2$ . A portion of the grape sugar is removed from solution by the chloroplast and converted into starch which is stored up within it; another portion is used to nourish the protoplasm of the cell. But the greater portion of sugar manufactured descends in solution through the phloem cells of the bundles of the veins, mid-rib and stipe to the stem or roots where it is removed from solution by the action of the leucoplasts which convert it into reserve starch. Sugar and starch, however, are not the only food materials manufactured in the leaf. Proteins are likewise formed. These are composed of carbon, hydrogen, oxygen, nitrogen, sulphur and sometimes phosphorus. They are formed from grape sugar with the addition of nitrogen and the other elements by the living protoplasm. The source of nitrogen, sulphur and phosphorus is the mineral salts which are found in the crude sap. These proteins descend through the sieve tubes of the veins, *midrib* and *petiole*, to the stem and roots nourishing all of these parts with protein material.

**Gross Structure and Histology of the Sori and Sporangia.**—The *sporangia* or spore cases are found clustered together in circular groups on the under surface of the *pinnules* nearer the mid-vein than the margin. Each group of sporangia is covered with a membranous expansion of the epidermis called the *indusium*. The whole is called a *sorus* (Fig. 2) (pl. sori) and contains many sporangia. Each *sporangium* is composed of: (a) the *stalk* of considerable length and usually comprising three rows of cells, outgrowths of the epidermis of the *pinnule*; and (b) the *head*, sub-globular and hollow, consisting for the most part of a covering of thin walled, flattened cells within which will be noted a marginal ring of cells with walls having U-shaped thickenings and called the *annulus*.

Within the sporangium are found the *spores*. Each spore is a single cell composed of an outer brown wall with band-like markings called an *exosporium*, an inner thinner wall or *endosporium*, and within this a mass of protoplasm containing a nucleus.

**Rupture of Sporangium and Spore Dissemination.**—As was previously indicated, each sporangial head has a row of cells with U-shaped thickenings around the margin called an annulus. As the sporangium matures the water escapes from the cells, pulling them together and holding the annulus like a bent spring. The thinner walled cells at the side of the spore case opposite the annulus, unable to stand the strain are consequently torn, the annulus straightens and a wide rent is made in the sporangium. The annulus then recoils and hurls the spores out of the sporangium. This closes the *sporophyte* generation.

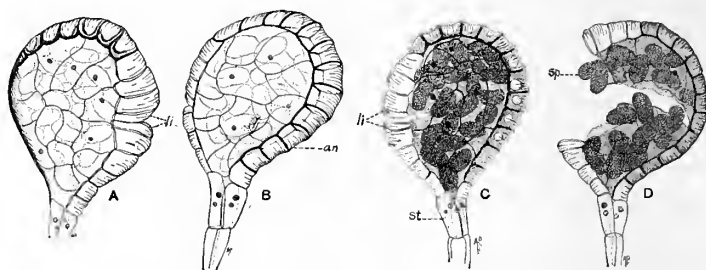


FIG. 3.—Sporangia of an undetermined species of fern; *li*, lip-cells; *an*, annulus; *st*, stalk; *sp*, mature spores. Each of the four nuclei in the upper cells of the stalk is in the terminal cell of one of the four rows of cells that compose the stalk. (Gager.)

**History of the Gametophyte or Sexual Generation.**—The fern spore, falling upon a moist surface, germinates, producing a delicate green septate filament called a *protonema*. One end of this structure shows larger cells which, by the formation of oblique walls, cut out an apical cell of somewhat triangular shape. This is the growing point of what eventually becomes a mature green heart-shaped body called the "*prothallium*" or "*prothallus*." The prothallium, about the size of an infant's finger nail, develops on its under surface *antheridia*, or male sexual organs, *archegonia*, or female sexual organs, and *rhizoids* or hair-like absorptive structures. The antheridia appear three to five weeks after spore germination. They are hemispherical in shape and are situated among the rhizoids toward the posterior end. Each antheridium consists of a three-celled wall which completely surrounds the *spermatocytes* or mother-cells of the spermatozoids. Within each *spermatocyte* the protoplasm arranges itself



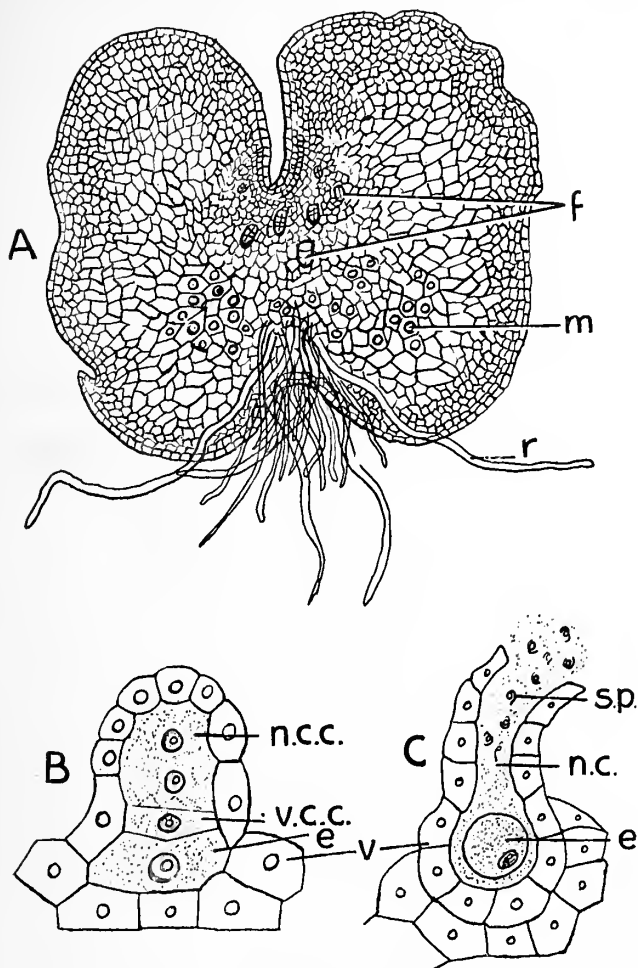


FIG. 4.—A, under surface of a fern prothallium showing archegonia (*f*), antheridia (*m*) and rhizoids (*r*); B, immature archegonium showing binucleate neck canal cell (*n.c.c.*), ventral canal cell (*v.c.c.*), and egg (*e*); C, mature archegonium showing sperms (*sp.*) moving through neck canal (*n.c.*) toward ovum (*e*), and venter (*v*). All highly magnified.

in a spiral fashion forming a *spermatozoid*, a spiral, many ciliated, male sexual cell. From two to four weeks after the maturation of the antheridia, the *archegonia* make their appearance toward the indented apex of the lower prothallial surface as outgrowths of the *prothallial cushion*. Since they appear later than the antheridia they are not likely to be fertilized by spermatozoids from the antheridia of the same prothallium. Each *archegonium* is composed of a *venter*, *neck*, *neck canal-cells*, *ventral canal-cell*, and *ovum* or egg-cell. The neck is composed of cells arranged in four rows, forming a cylinder, one layer of cells thick. This protrudes from the surface of

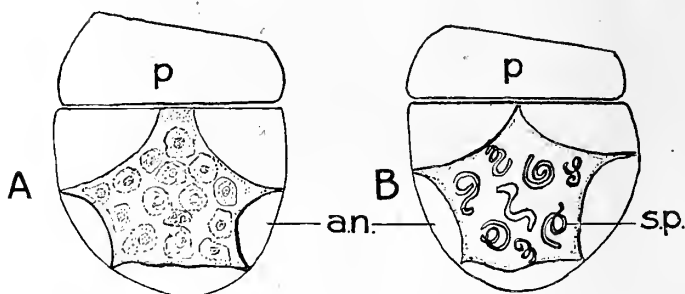


FIG. 5.—A, median longitudinal section through immature antheridium, and cell of prothallium showing prothallial cell (*p*), and antheridial wall surrounding a number of spermatocytes; B, similar section through mature antheridium and cell of prothallium showing fully developed spermatozoids (*sp.*) enclosed by wall of antheridium. Both highly magnified.

the prothallium and encloses the neck canal-cells and ventral canal-cell. The ovum is embedded in the prothallial cushion just beneath the ventral canal-cell. Upon the maturation of the archegonium, the canal-cells are transformed into a mucilaginous substance which fills a canal extending from the outside opening (mouth) to the ovum.

During wet weather the mature antheridial wall bursts open and the many ciliated *spermatozoids* escape into the water. These moving in the water are drawn by the chemotactic malic acid to the mouths of the archegonia of another prothallus and, passing down the canal of each of these, gather around the ovum. One, probably the best adapted, fuses with the ovum and fertilizes it forming an *öospore* or fertilized egg.

**Origin of New Sporophyte or Diploid Plant from Fertilized Egg.**—

The fertilized egg now rapidly divides and redivides to form *octant* cells. The octant cells further divide to produce anteriorly a *stem rudiment* (one cell), *first leaf* (two cells), *second leaf* (one cell) and, posteriorly, *root rudiment* (one cell), *foot rudiment* (two cells) and *hair rudiments* (one cell).

**Growth of Seedling into Mature Sporophyte.**—The foot rudiment develops into the foot which obtains nourishment from the prothallium upon which the young sporophyte is for a time parasitic. The root rudiment becomes the first root which grows downward into the soil. The stem and leaves turn upward. In a few weeks the prothallus decays and the sporophyte is established as an independent plant. More roots and leaves (fronds) are developed and ere long continued growth results in the formation of a mature sporophyte which presents for examination: (1) a *subterranean stem* bearing several *roots*; and (2) *aerial fronds*, each of which consists of a *stipe* or *petiole* and a *lamina* or *blade*, divisible into *pinnæ* or *lobes* and *pinnules*, upon which last *sori* are developed.

**Alternation of Generations.**—It will be observed that in the life cycle of the Male Fern there occur two distinct generations, one, a sporophyte or asexual generation which begins with the oöspore and ends with the dispersion of asexual spores; a second, the gametophyte or sexual generation beginning with the protonemal outgrowth of the spore and ending with the fertilization of the egg to form an oöspore. The sporophyte gives rise to the gametophyte which in turn gives origin to the sporophyte.

## CHAPTER III

### LIFE HISTORY OF A GYMNOSPERM (PINUS STROBUS)

The White Pine frequently called the Weymouth Pine (*Pinus Strobus*), one of the principal timber trees of the Northern States and Canada, is also of value in pharmacy and medicine. The inner bark of its trunk and branches is used because of its valuable expectorant properties and is official in the N. F. IV.

#### DESCRIPTION OF THE WHITE PINE TREE (MATURE SPOROPHYTE)

From an underground spreading root system there arises an erect aerial *trunk* or stem that extends from the ground to the apex of the tree, ending in a terminal bud. The trunk rarely exceeds 3 feet in diameter and 125 feet in height and is averagely  $1\frac{1}{2}$  to 3 feet in diameter and 50 to 90 feet high. At a varying distance above the soil, depending upon enviroinal conditions as well as the age of plant, whorls of lateral branches (three to seven in a whorl) are seen emanating from the trunk in horizontal fashion at various levels up to near the apex. These become, under conditions prevalent when the tree is grown in the open, gradually shorter until the summit is reached, giving to the *crown* or upper part of the tree the appearance of a pyramid. These branches give rise to other branches which agree with the lateral branches in bearing commonly only scale-like leaves as well as ending in terminal buds. Another kind of branch, however, is found which is always shorter than the scaly branches. This type of branch is called a "*spur shoot*" and arises from the former branches. The spur shoots bear the *needles* or *foliage leaves* which are light green when young and bluish-green, soft, flexible,  $2\frac{1}{2}$  to 5 inches long when mature. The "needles" occur in tufts (*fascicles*) of five, are triangular in cross-section, have finely *serrate* (*saw-toothed*) edges and are surrounded at the base by a deciduous

sheath. These foliage leaves persist until the end of their second year when they are shed with the spur shoot which bears them.

The white pine, like most of its allies among the Coniferæ, bears cones. These structures are of two kinds, viz.: staminate and carpellate. Both kinds are produced on the same tree.

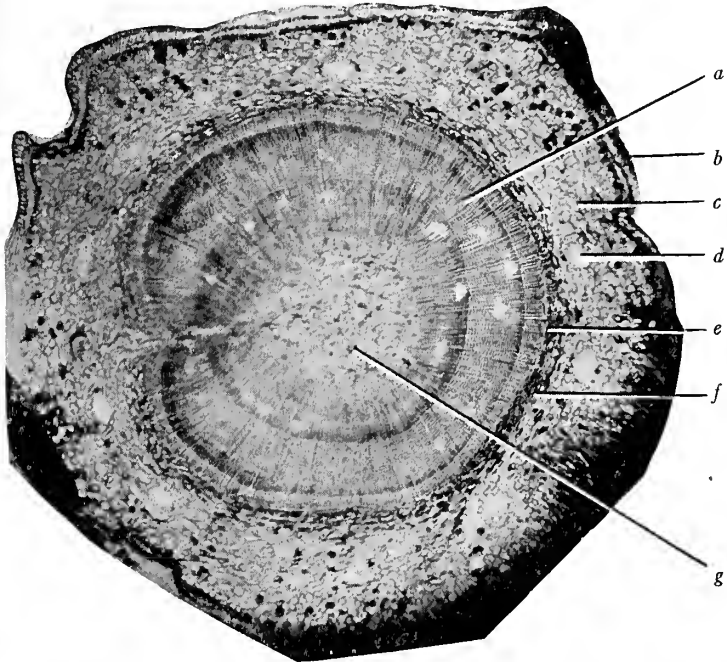


FIG. 6.—Transverse section of pine stem in third year of growth showing xylem (a), cork (b), cortex (c), secretion reservoir (d), cambium (e), phloem (f), and pith (g). (Photomicrograph.)

**Staminate Cones.**—The yellow, ovate, staminate cones appear about May and are clustered at the base of the new growth of the current season. Each consists of a main axis (modified branch) which bears spirals of scales (*microsporophylls* or *stamens*). On the under surface of each scale are the spore-cases (*microsporangia*), which develop the *microspores* (*pollen grains*). Each pollen grain when mature consists of a central fertile cell and a pair of air-sacs

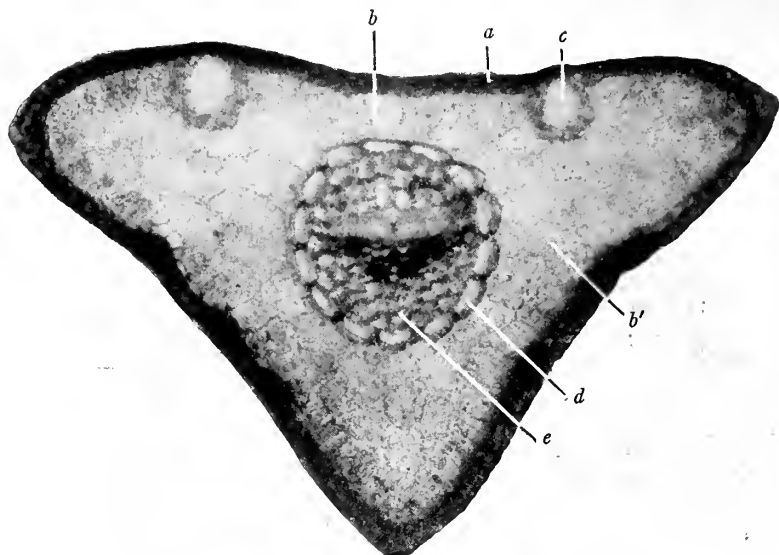


FIG. 7.—Transverse section of white pine needle (leaf) showing epidermis (a), infolded parenchyma cells of mesophyll (b, b'), oil reservoir (c), endodermis (d), and clear cellular area surrounding fibrovascular tissue in center (e).

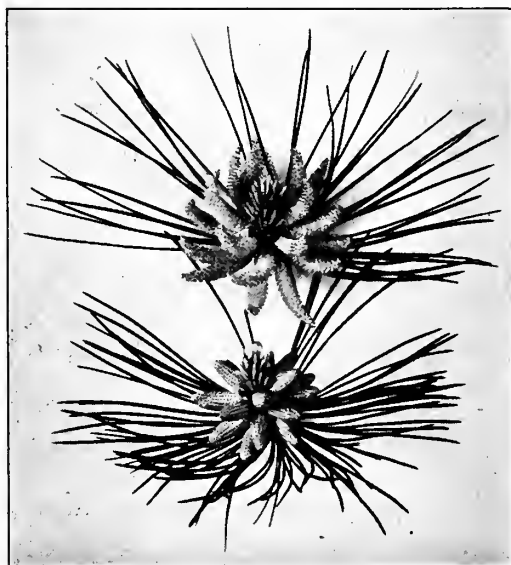


FIG. 8.—Staminate cones of the Austrian pine (*Pinus austriaca*). Below, before shedding pollen; above, after shedding. (Gager.)

or wings, one on either side of the fertile cell. The purpose of the latter is to give greater buoyancy in the air to the microspore.

**Carpellate Cones.**—The young carpellate cones appear in May or early June as pinkish-purple structures arranged in solitary fashion or in small groups, lateral along the new growth. Each terminates

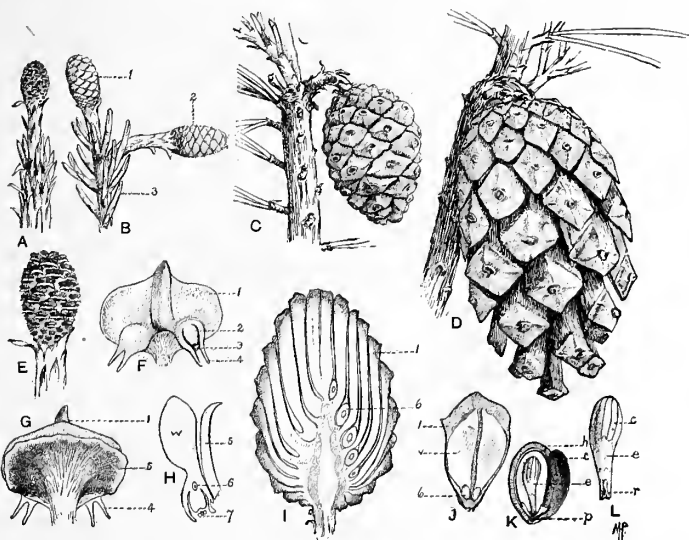


FIG. 9.—Scotch pine (*Pinus sylvestris*). A–D, stages in the development of the carpellate cone, and its carpotropic movements. E, very young carpellate cone much enlarged; F, ventral, G, dorsal views of a scale from E; I, ovuliferous scale; 2, ovule (in longitudinal section); 3, pollen chamber and micropyle leading to the apex of the nucellus (megasporangium); 4, integument of the ovule; G, I, tip of ovuliferous scale; 5, bract; 4, integument; H, longitudinal section at right angles to the surface of the ovuliferous scale (diagrammatic); 6, megaspore; 7, pollen chamber; I, longitudinal section of a mature cone; 6, ovule; J, scale from a mature cone; 6, seed; w, wing of seed; K, dissection of mature seed; h, hard seed coat; c, dry membranous remains of the nucellus, here folded back to show the endosperm and embryo; e, embryo; p, remains of nucellus; L, embryo; c, cotyledons; e, hypocotyl; r, root-end. (Gager.)

a lateral axillary branch. A carpellate cone is composed of a main axis which bears spirals of scales, by some termed *megasporophylls* (*carpels*). Each scale is composed of an ovuliferous scale bearing two *ovules* or *megasori* and a bract. Each megasorus contains a *nucellus* or *megasporangium* which is surrounded by an integument

except at the apex where an opening, the micropyle is evident. The micropyle is the gateway to the *pollen chamber* which lies below it. Within the nucellus occurs a *megaspore* or *embryo sac*.

### DESCRIPTION OF THE GAMETOPHYTE GENERATION

The Gametophyte generation of the White Pine begins with the development of the male and female gametophytes and terminates with the fertilization of the egg.

**The Male Gametophyte.**—The male gametophyte commences to form in the mature pollen grain before the pollen is shed. A series of three nuclear divisions takes place which cut off two small prothallial cells (traces of one of which may be seen pushed up against the wall of the fertile cell of the pollen grain), a tube nucleus and a generative cell. At this stage the pollen is shed and some of it is

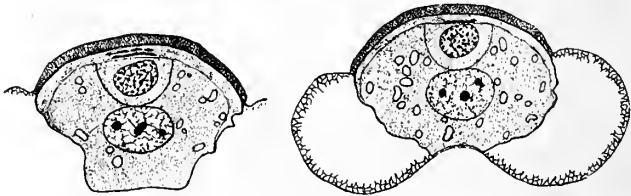


FIG. 10.—The white pine (*Pinus Strobus*). Sections through mature pollen grains; at the left the remnants of two prothallial cells can be seen, while at the right all signs of the first cell have disappeared. Pollen collected June 9, 1898. X about 600. (Gager, after Margaret C. Ferguson.)

carried by air currents to the carpellate cones where it sifts in between the ovule-bearing scales and accumulates at the scale bases. This is *pollination*. A number of the pollen grains are drawn close to the nucellus of the ovule by the drying up of the viscid fluid which fills the *pollen chamber*. In this fluid they germinate forming pollen tubes. The transfer of pollen grains from the pollen sac to the pollen chamber and consequent germination therein is called *pollination*.

**The Female Gametophyte.**—If the embryo sac be examined at about the time of pollination, it will be found to consist of a single cell containing a single nucleus surrounded by cytoplasm. Very shortly afterward, however, the nucleus divides repeatedly to form a



large number of nuclei which are scattered throughout the cytoplasm. Each nucleus accumulates around itself a portion of the cytoplasm and ultimately cell walls are laid down and the entire embryo sac contains *endosperm* (prothallial) tissue. Toward the micropylar end of the endosperm (*prothallus*) originate several archegonia.

Each archegonium consists of a much-reduced neck of four cells and an egg (*ovum*) which lies embedded in the prothallus which forms a narrow layer of cells around it called the *jacket*. The contents of the mature embryo sac constitutes the female gametophyte.

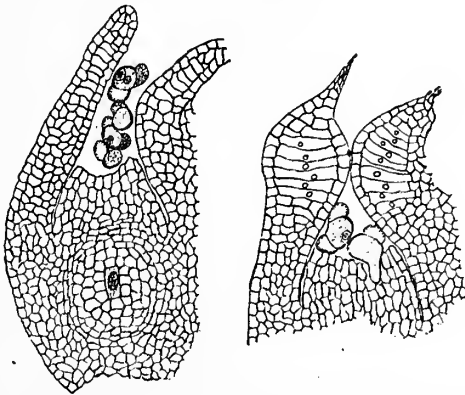


FIG. 11.—White pine (*Pinus Strobus*). At left, megasporangium with megaspore in the center; above, pollen grains in the micropyle and pollen chamber. At right, pollen grains beginning to germinate; the cells of the integument have  $\times$  enlarged and closed the micropyle. (Gager, after Margaret C. Ferguson.)

**Fertilization.**—About a year after pollination the pollen tubes, lying within the pollen chamber show signs of renewed activity. The tube nucleus passes to the tip of the tube. The generative-cell divides to form a body and a stalk-cell which pass into the tube. The body-cell later forms two sperm nuclei. While these changes are taking place the tube is penetrating the nucellus and growing toward the embryo sac with its contained female gametophyte. It finally enters it, passing between the neck-cells of the archegonium. The tip of the tube then breaks and the entire tube contents is emptied into the egg. One of the sperm nuclei fuses with the egg nucleus and fertilizes it forming an oöspore.

**Seed Formation and Distribution.**—The oöspore undergoes repeated divisions and forms the embryo or young sporophyte plant and a suspensor to which it is attached. The embryo is nourished by a portion of the prothallus but the greater part of the prothallus forms the endosperm tissue of the seed surrounding the embryo. The thin nucellus persists as an endosperm covering. The integument becomes modified to form the hard protective seed coat: A

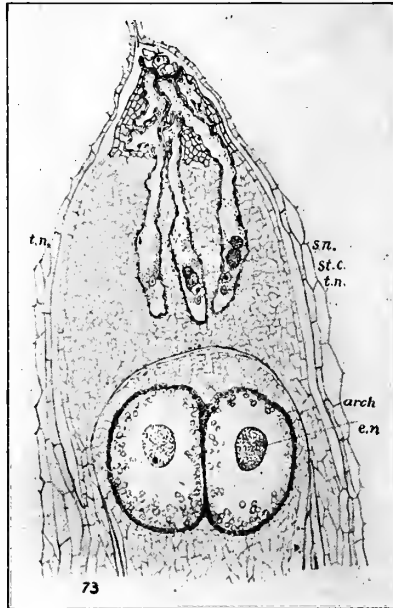


FIG. 12.—White pine (*Pinus Strobus*). Vertical section through the upper part of an ovule, shortly before fertilization. *s.n.*, sperm-nuclei; *st. c.*, stalk-cell; *t.n.* tube-nucleus; *arch*, archegonium; *e.n.*, egg-nucleus. (Gager, after Margaret C. Ferguson.)

portion of the scale of the cone directly above and adjacent to the ovule forms a membranous wing which separates from the scale as part of the seed.

By this time (about two years after pollination) the scales of the cone, now quite woody, separate, the seeds are shaken out, and many are carried for a considerable distance by winds.

**Germination of the Seed.**—Under favorable conditions, the seeds absorb water and germinate in the spring following their dispersal. The hypocotyl of the embryo appears first, arching upward and downward, and, straightening out, draws the green cotyledons with it which spread out toward the light while it grows into the soil to form the tap root and in time the remainder of the root system. Thus the seedling sporophyte is formed which in time develops into the mature White Pine tree.

## CHAPTER IV

### LIFE HISTORY OF AN ANGIOSPERM (ERYTHRONIUM AMERICANUM)

This attractive little plant, commonly called the Dog's Tooth Violet but related to the Lily, is found in the hollows of woods and may be seen in flower during the month of April in the Middle Atlantic States. It consists of an underground *stem* bearing *scales* (modified leaves) which is termed a *bulb*. From the lower surface of the bulb are given off numerous slender *rootlets* which penetrate the soil and from the upper surface, a pair of oblong lance-shaped *leaves* of pale green color mottled with purple and white and later, a *flower stalk* (*scape*) which bears upon its summit a single yellow nodding flower which is often marked with purple stripes. The flower consists of a *torus* or *receptacle* which will be observed as the upper swollen end of the flower stalk (*scape*). Inserted upon it, passing from periphery toward the center, will be noted four whorls of floral leaves which in order are *calyx*, *corolla*, *andræcium* and *gynæcium*. The calyx is composed of three lance-shaped and recurved yellow parts called *sepals*; the corolla of three similarly looking parts called *petals* which alternate in position with the sepals. Both of these whorls are collectively called the *perianth* or floral envelope. The andræcium or male system of organs is composed of two whorls or circles of structures called *microsporophylls* or *stamens*. There are three *stamens* in each whorl. The outer whorl of stamens will be found opposite the sepals while the inner will be observed opposite the petals. Each stamen (microsporophyll) consists of an awl-shaped stalk or *filament* bearing upon its summit an oblong-linear body called an *anther*. The anther consists of two lobes called *microsori*. Each lobe or microsorus contains two anther sacs or *microsporangia* in which when mature are to be found *microspores* or pollen grains. In the center of the flower will be noted

the gynœcium or female system of organs. This, upon dissection, will be found to consist of three fused carpellary leaves termed *mega-sporophylls* (carpels) forming a somewhat flask-shaped structure called a *pistil*. The swollen basal portion of the pistil is called the *ovary*; the stalk which arises from it is called the style and the knob-like viscid summit of the style is termed the *stigma*.

*Development of the Female Gametophyte Through the Maturation of the Embryo Sac.*—In its immature condition the *embryo sac* (*mega-spore*) contains a mass of protoplasm surrounding a nucleus. This nucleus undergoes three divisions forming as a result eight nuclei which ultimately arrange themselves within the protoplasm of the embryo sac as follows: three of them occupy a position at the apex, the lower nucleus of the group being that of the egg or *ovum*, the other two nuclei being the *synergids* or assisting nuclei; at the opposite end of the sac three nuclei known as *antipodals* take their position; the two remaining nuclei called *polar nuclei* take up a position near the center of the embryo sac. In this condition the contents of the embryo sac constitutes the *female gametophyte*.

### POLLINATION AND FERTILIZATION

The mature pollen grains are discharged from the ripened anther through the splitting open of its wall. They are transferred to the stigma of the pistil of another *Erythronium* flower through the agency of insects. Here they germinate, each putting forth a tube (pollen tube). The pollen tubes, carrying within it two sperm nuclei and a tube nucleus embedded in protoplasm, penetrate through the style canal until they reach the micropyles of various ovules. Each enters and passes through a micropyle, then piercing the nucellus, grows toward the embryo sac. The tip of the tube fuses with the end of the embryo sac and the two sperm nuclei are discharged into the sac. One of these sperm nuclei passes between the synergids and fuses with the nucleus of the egg to form an *oöspore*. By this time the tube nucleus has disintegrated. The *oöspore* by repeated divisions develops into as many as four *embryos* or young sporophyte plants. Only one of these, however, persists. The polar nuclei fuse to form the *endosperm nucleus* which soon undergoes rapid division into a large number of nuclei scattered

about through the protoplasm of the embryo sac. Later cell walls are laid down and *endosperm* is formed. The endosperm cells soon become filled with abundant starch which is later to be utilized by the embryo during germination.

Microscopical examination of sections of the ovary will reveal it to be composed of three chambers called *locules* within each of which are to be noted several inverted *ovules*. Each of these ovules is developed upon a nourishing tissue termed "*placenta*" which connects the ovules to the inner angle of the wall of the locule. The ovule is composed of a central prominent *megasporangium* or *nucellus* which is almost completely invested by two upgrown integuments or coverings. The opening between the tips of the inner integument is called the *micropyle* (little gate). This is the gateway for the entrance of the pollen tube on its way to the nucellus. It is also the exit door for the hypocotyl of the embryo after the fertilized and ripened ovule becomes a seed. Within the nucellus, if the sections examined have been properly fixed, will be found a *megaspore* or *embryo sac*.

#### MATURATION OF THE POLLEN GRAIN AND FORMATION OF THE MALE GAMETOPHYTE

The pollen grains (microspores) within the anther sacs all arise from a number of tetrads (groups of four) which are formed by the division and redivision of pollen mother-cells preceding them. Each pollen grain, after the tetrads have separated into their components, consists of an outer firm wall or *exosporium*, an inner wall or *endosporium*, within which will be found the region called the *fovilla*, which is nothing other than a mass of protoplasm containing a nucleus. Before the pollen is shed from the anther its protoplasmic contents undergo a series of changes leading up to the development of the male gametophyte. The nucleus and protoplasm enveloping it divide to form two cells, one a generative-cell containing a generative nucleus, the other a tube-cell containing a tube nucleus. The generative nucleus then divides to form two sperm nuclei and the partition wall between the two cells disappears. In this condition the protoplasmic contents of the pollen grain constitute the male gametophyte.

### RIPENING OF THE OVULE TO FORM THE SEED AND OF THE OVARY TO FORM THE FRUIT

While the embryo and endosperm are being formed, the ovule enlarges and its integuments become modified to form a hard horny seed coat which encloses the endosperm surrounding the embryo. The ovary, containing the ovules, has by this time ripened to form a three-valved loculicidal capsule enclosing the seeds.

### GERMINATION OF THE SEED AND DEVELOPMENT OF THE MATURE SPOROPHYTE

The seeds are fully developed by June or July when the capsule or fruit splits open to discharge them. They fall to the ground and lie dormant until the following spring when they germinate or commence to grow. Each seed absorbs water from the ground which stimulates the ferment amylase, contained in the endosperm cells, to break up the insoluble starch into soluble sugar which passes into solution and diffuses into the cells of the embryo where the protoplasm changes it into additional protoplasm and so the embryo increases in size, therefore, *grows*. The pressure of the swollen endosperm and growing embryo becomes so great that the seed coat bursts; the hypocotyl emerges first, dragging the cylindrical cotyledon out of the seed coat and epicotyl with it. The hypocotyl elongates and extends itself into the soil where it develops a root near its tip. The tip enlarges through the storage of starch, manufactured by the green cotyledon and becomes a bulb. The bulb soon develops within it a plumule, the cotyledon withers, and the young plant (seedling) passes the following winter in this condition.

During the next spring the plumule develops into a foliage leaf and the bulb gives rise from its base to several slender elongated *runners*, which, at their tips develop *runner bulbs*. These runner bulbs the third year give origin to another set of runners similar to those formed during the second year which also develop runner bulbs at their tips. A foliage leaf is also formed by each. The following spring (spring of fourth year) one of these bulbs develops into a mature sporophyte plant bearing a single flower at the summit of its elongated scape.

**RESEMBLANCES BETWEEN GYMNOSPERMS AND ANGIOSPERMS**

1. In both are developed those structures in which there is no homologue, *e.g.*, flowers.
2. In both the flowers develop at least two sets of leaves (either on one or two plants of the same species) called sporophylls or sporophyll leaves, the stamens and carpels. The stamens or staminal leaves are also termed microsporophylls. The carpels or carpellate leaves are also known as megasporophylls.
3. Both groups produce microspores or pollen grains and megaspores or embryo sacs.
4. In both are developed on the evident generation, the plant or sporophyte and the gametophyte, the latter concealed within the megaspore of the sporophyte.
5. Both develop seeds with one or two seed coats.
6. In both groups there is developed from the fertilized egg an embryo which lies within the cavity of the megaspore.
7. In both there exists a root and a stem pericambium.
8. Both produce collateral vascular bundles. Very rarely do we meet with concentric bundles in the stem or leaf of Angiosperms.

**FUNDAMENTAL DIFFERENCES BETWEEN GYMNOSPERMS AND ANGIOSPERMS**

1. The flowers of Gymnosperms are often monœcious or diœcious but very rarely hermaphrodite as in *Welwitschia*, whereas those of Angiosperms are usually hermaphrodite, rather rarely monœcious, still more rarely diœcious.
2. In the Gymnosperms the sporophylls are usually inserted either spirally or in whorls around a distinctly elongated axis, whereas in Angiosperms the sporophylls are condensed to short whorls or spirals set around a shortened axis, the floral axis or receptacle, torus or thalamus, or, as in the more modified Angiosperms, the floral axis may even become hollow.
3. In Gymnosperms the microsporophylls or stamens are usually sessile, whereas in Angiosperms the microsporophylls are nearly always stalked. Rarely do we find sessile anthers among Angio-



sperms, an instance of this being seen in Mistletoe (*Viscum*) where the anthers are set on the staminal leaf.

4. In Gymnosperms there is a traceable prothallus or gametophyte plant that later becomes the so-called "endosperm" of the gymnosperm, whereas in Angiosperms no recognizable prothallus has been proven to exist.

5. The stored food tissue in Gymnosperm seeds is prothallial tissue loaded with starch, etc., whereas in Angiosperm seeds the stored food tissue (endosperm) is a special formation after fertilization.

6. Angiosperms bear naked ovules and seeds while Gymnosperms bear covered ones.

7. In Gymnosperms there are distinct recognizable archegonia formed on or imbedded in the prothallus, whereas in Angiosperms there are no distinct archegonia, only an isolated egg or eggs.

8. In Gymnosperms there are not infrequently found several embryos from one fertilized egg. This condition is called *polyembryony*. Polyembryony is unknown in Angiosperms, only a *false polyembryony* being noticed.

9. In Gymnosperms the secondary xylem (wood) tissue of roots, stems and leaves consists either of punctated or scalariform cells, whereas in Angiosperms the secondary wood tissue may be varied in structural aspect.

## CHAPTER V

### VEGETABLE CYTOLOGY

*Vegetable Cytology* treats of plant cells and their contents.

#### THE PLANT CELL AS THE FUNDAMENTAL UNIT

Schleiden, in 1838, showed the cell to be the unit of plant structure. The bodies of all plants are composed of one or more of these fundamental units. Each cell consists of a mass of protoplasm which may or may not have a cell wall surrounding it. While most plant cells contain a nucleus and some contain a number of nuclei, the cells of the blue-green algæ and most of the bacteria have been found to lack definitely organized structures of this kind but rather contain chromatin within their protoplasm in a more or less diffuse or loosely aggregated condition.

#### A TYPICAL PLANT CELL

If we peel off a portion of the thin colorless skin or *epidermis* from the outer convex surface of an onion bulb scale, mount in water and examine under the microscope, we find it to be composed of a large number of similar cells which are separated from one another by means of lines, the bounding cell walls. Under high power each of these cells will exhibit the following characteristics:

An outer wall, highly refractile in nature and composed of *cellulose* which surrounds the living matter or *protoplasm*. This wall is not living itself but is formed by the living matter of the cell. Somewhere within the protoplasm will be noted a denser-looking body. This is the *nucleus*. Within the nucleus will be seen one or more smaller highly refractile and definitely circumscribed *bodies*, the *nucleolus* or *nucleoli*. The protoplasm of the cell outside of the nucleus is called the "*cytoplasm*." It will be seen to be clear and

granular-looking. Within the cytoplasm will be observed a number of clear spaces. These are *vacuoles* and because they are filled with *cell sap* (water with nutrient substances in solution) are called "*sap vacuoles*."

Protoplasm is in intimate relation to water. The reaction of the cytoplasm to a bounding film of water between it and the cell wall forms the *outer plasma membrane* or *ectoplasm*, a clear homogeneous outer band of cytoplasm; the reaction of cytoplasm to the water within the sap vacuoles forms the *vacuolar membranes*; the reaction of the dense protoplasm of the nucleus to the water in the cytoplasm around it forms the *nuclear membrane*. Upon mounting another portion of epidermis in iodine solution, removing the excess of stain and adding a drop of sulphuric acid and then examining under high power, we note that the cell walls of cellulose are stained a deep blue. A yellow line is evident in the middle of each cell wall and separates each cell from its bounding cells. This line is the *middle lamella* which is composed largely of *calcium pectate*.

## PROTOPLASM AND ITS PROPERTIES

**Protoplasm**, or living matter, is the more or less semi-fluid, viscid, foamy, and granular substance in which life resides. It is the "physical basis of life."

The peculiar properties which distinguish protoplasm from non-living matter are as follows:

1. **Structure**.—Protoplasm invariably exhibits structure. No portion of it, however small, has been found to be homogeneous. Each advance in microscopical technique reveals new complexities. The protoplasm of a single cell, far from being a single unit, must rather be looked upon as a microcosm.

2. **Metabolism**.—Perhaps the most significant peculiarity of living matter is found in its instability and the chemical changes which continually go on within it. It is constantly wasting away, and as constantly being built up. These losses and gains are not upon the exterior surface, but throughout its mass. Its growth and renewal are by *intussusception*, or the taking in of new particles and storing them between those already present. A bit of protoplasm may re-

tain its identity while all the matter of which it is composed is changed over and over. It is like a whirlpool or wave in a river which remains the same while the water of which it is composed changes continually. Metabolism has been aptly defined by Huxley as the whirlpool character of the organism.

3. **Reproduction.**—Protoplasm also shows a very remarkable ability to increase and to give off detached portions which retain the infinitely complex peculiarities and properties of the original. The process, moreover, may be continued indefinitely.

Other physiological characteristics might be added, but the above are mentioned as the most satisfactory criteria by which living may be distinguished from non-living matter.

### PROTOPLASMIC CELL CONTENTS

Protoplasm consists of four well-differentiated portions:

(a) **Cytoplasm**, or the foamy, often granular matrix of protoplasm outside of the nucleus.

(b) **Nucleus** or **Nucleoplasm**, a denser region of protoplasm containing chromatin, a substance staining heavily with certain basic dyes.

(c) **Nucleolus**, a small body of dense protoplasm within the nucleus.

(d) **Plastids**, composed of plastid plasm, small discoid, spheroidal, ellipsoidal or ribbon-shaped bodies scattered about in the cytoplasm. Sometimes, as in the cells of lower plants like the Spirogyra, plastids are large and are then called **chromatophores**.

According to the position of the cells in which plastids occur and the work they perform, they differ in color, viz.:

**Leucoplastids** are colorless plastids found in the underground portions of a plant and also in seeds, and other regions given up to the storage of starch. Their function is to build up reserve starch from sugar and other carbohydrates as well as to change the reserve starch back into sugar when it is needed for the growth of the plant. They are only evident after properly fixing and staining cells containing them.

**Chloroplastids** are plastids found in cells exposed to light and contain the green pigment, chlorophyll.

**Chromoplastids** are plastids found in cells independent of their relation to light or darkness and contain a yellow, orange or red pigment called chromophyll.

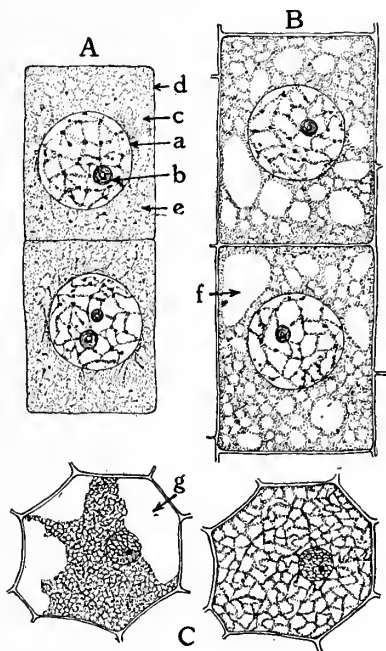


FIG. 13.—A, embryonic cells from onion root tip; *d*, plasmatic membrane; *c*, cytoplasm; *a*, nuclear membrane enclosing the thread-like nuclear reticulum; *b*, nucleolus; *e*, plastids (black dots scattered about). B, older cells farther back from the root tip. The cytoplasm is becoming vacuolate; *f*, vacuole. C, a cell from the epidermis of the mid-rib of *Tradescantia zebrina*, in its natural condition on the right, and plasmolyzed by a salt solution on the left; *g*, space left by the recedence of the cytoplasm from the wall; the plasma membrane can now be seen as a delicate membrane bounding the shrunken protoplast. All highly magnified. (Stevens.)

### CELL FORMATION AND REPRODUCTION

The cells of plants have all been derived from preëxisting cells. In the bacteria and many other low forms of plant life, the division of the cell always results in reproduction; in higher forms, however, it merely increases the size of the individual and so is a phenomenon of growth.

There are two kinds of cells formed by plants, viz.: *asexual* and *sexual*. Both of these are endowed with the possibilities of reproduction, although the former are frequently limited to the process of growth.

*Reproduction* is the power possessed by an organism of giving rise to new individuals. This may take place through the agency of either asexual or sexual cells and is accordingly asexual or sexual in character. Whenever a union of cells or their protoplasmic contents takes place the process is called "sexual reproduction;" if, however, there is a mere separation of a cell or cells from an individual which later form a new organism, the process is termed "asexual or vegetative reproduction."

There are four modes of asexual reproduction, viz.: *Fission*, *Gemmation*, *Free Cell Formation* and *Rejuvenescence*.

**Fission.**—This is the separation of a cell into two equal halves, each of which may grow to the size of the original parent cell from which it was derived. Fission is seen in the reproduction of bacteria, growth of many algæ and the formation of tissues of higher plants.

**Gemmation** or **Budding.**—This is the method of reproduction common among yeasts. The cell forms a protuberance called a bud which increases in size until it equals the size of the cell which formed it and then becomes detached, although frequently not until it has developed other buds and these still others.

**Free Cell Formation.**—This is a type of reproduction in which the nucleus and protoplasm become separated into two or more masses each of which forms a cell wall about itself. Seen in formation of ascospores within ascus of Ascomycetes and spores within spore cases of molds.

**Rejuvenescence.**—In this mode of reproduction the protoplasm of the cell becomes rounded out, escapes by rupture of the cell wall, forms cilia and moves about as a *zoöspore*. Later it loses its cilia, develops a cell wall and passes into a resting condition. Under favorable circumstances it grows into a new organism. It is found in *Œdogonium*, *Ectocarpus*, etc.

There are two kinds of sexual reproduction, viz.: *Conjugation* and *Fertilization*. In both of these the sexual cells called *gametes* or

their nuclei come together and their protoplasm blends to form a new cell. This is the common method seen in higher plants.

**Conjugation.**—A union of two gametes, alike in character, the product being a *zygote* or *zygospore*. This method of reproduction is seen in the molds, Spirogyra, Zygnema and Diatoms.

**Fertilization.**—A union of two unlike gametes or their nuclei, the product being an oöspore. One gamete, the male sexual cell, is smaller and active while the other, the female sexual cell is larger and passive. This process is seen among the higher and many of the lower plants.

### INDIRECT NUCLEAR DIVISION (MITOSIS OR KARYOKINESIS)

This is the general method of division seen in the formation of tissues of higher plants.

The process begins in the nucleus and ends with the formation of a cell wall dividing the new-formed cells.

When we examine a cell in its *resting stage* we find the nucleus more or less spherical in shape, surrounded by a *nuclear membrane* and containing a *nuclear network*, *nuclear sap* and one or more *nucleoli*. The nuclear network consists of a colorless network of *linin* adhering to which are numerous minute granules called *chromatin* which take the stain of a basic dye. Surrounding the nucleus is the *cytoplasm*.

As the cell commences to divide, the nucleus elongates and the linin threads of the nuclear reticulum shorten, drawing the chromatin granules together into a thickened twisted chromatic thread. This thread splits transversely and thus becomes divided into a number of rods termed *chromosomes*. Each of these then splits into two longitudinal halves that may be termed the *daughter-chromosomes*. They lie within the nuclear cavity united by delicate threads. There now begins a phenomenon concerned with the cytoplasm which is primarily a process of spindle formation. The granular cytoplasm accumulates at the poles of the elongated nucleus forming the *cytoplasmic caps*. Presently it begins to show a fibrillar structure, the threads extending outward around the periphery of the nucleus forming an umbrella-like arrangement of fibers from both

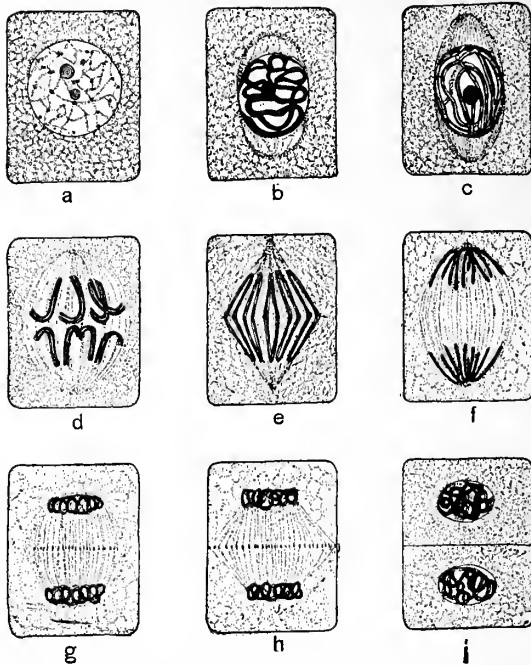


FIG. 14.—Semi-diagrammatic representation of nuclear and cell-division. *a*, resting cell ready to begin division; *b*, the nuclear reticulum is assuming the form of a thickened thread, and the cytoplasm at opposite poles is becoming thread-like to form the spindle fibers; *c*, the nuclear thread has divided longitudinally through the middle, and the spindle fibers have become more definite; *d*, the nuclear membrane and the nucleolus have disappeared, and the nuclear thread has become segmented into chromosomes which are assembling at the equator of the cell. All of the phases of division thus far are called *prophases*. *e*, the metaphase, where the longitudinal halves of the chromosomes are being drawn apart preparatory to their journey toward the opposite poles; *f*, the anaphase, or movement of the chromosomes toward the poles, is about completed, connecting fibers extend from pole to pole; *g*, telophase where the chromosomes have begun to spin out in the form of a nuclear reticulum. The connecting fibers have begun to thicken in the equatorial plane; *h*, the connecting fibers have spread out and come into contact with the wall of the mother cell in the equatorial plane, and the thickening of the fibers throughout this plane has made a complete cell plate within which the dividing wall will be produced; *i*, a nuclear membrane has been formed about each daughter nucleus, and the dividing cell-wall is completed. The two daughter cells are now ready to grow to the size of the parent cell in *a*, when the daughter nuclei will appear as does the nucleus there. All highly magnified. (*Stevens.*)



cytoplasmic caps. With the formation of fibers comes a breaking down of the nuclear membrane and in consequence the fibers enter the nuclear cavity and organize the *spindle*. Some of the fibers become attached to the split chromosomes and push, draw or pull them to the *equatorial plate*, halfway between the poles. Meanwhile the nucleolus disappears. As the chromosomes line up at the *equatorial plate* their daughter halves are drawn apart in V-shaped fashion. The split extends and eventually one daughter-chromosome is drawn to one pole and the remaining half to the other. At the respective poles the daughter chromosomes form a dense compact knot. A cell membrane, composed of material contributed largely through the shrinking of the spindle fibers, is now formed through the middle of the spindle. This soon splits to form a thin vacuole lying between the two membranes (the *plasma membranes*). Presently there appears within the vacuole and between the membranes a carbohydrate substance. On either side of this deposit the plasma membranes form a cellulose membrane. The flattened vacuole extends toward the periphery and ultimately a complete cell wall is formed.

The dense compact knots of chromosomes at the poles of the spindle, that are to form the daughter-nuclei, now begin to expand and clear mesh-like spaces to appear between the expanding threads. As this process advances the chromosome substance becomes distributed throughout the nuclear cavity. It is soon possible to distinguish the chromatin from the linin. Eventually an irregular network of linin carrying chromatin granules is formed through the area of the nucleus. A nuclear membrane also is formed and the nucleolus reappears. The spindle fibers disappear. The daughter-nuclei increase in size and each *daughter-cell* formed by this process now assumes the resting stage.

#### NON-PROTOPLASMIC CELL CONTENTS

1. **Sugars.**—*Sugars* comprise a group of crystalline substances found in the cell sap of many plants either free or in combination with glucosides. They may be divided into two main groups: monosaccharoses and disaccharoses. To the former belong simple

sugars containing two to nine atoms of carbon, which are known respectively as bioses, trioses, tetroses, pentoses, hexoses, etc. Of these the hexoses ( $C_6H_{12}O_6$ ) are the most important and of wide distribution. Examples of the hexoses found in drug plants are: (a) dextrose (grape sugar), found in the leaves, stems, fruits, sprouting grains and nectaries of flowers of nearly all plants; (b) fructose (levulose or fruit-sugar), commonly associated with dextrose; (c) d-mannose, found in the saccharine exudation of the Manna Ash (*Fraxinus Ornus*); and (d) sorbinose, found in ripe Mountain Ash berries. Upon evaporating the sap or treating the parts containing these principles with alcohol they can be crystallized out.

Flückiger's Micro-chemic Test for the determination of different kinds of sugars: Dissolve a small portion of copper tartrate in a drop of sodium hydrate on a glass slide; in this place the section and put on the cover slip. If fructose is present cuprous oxide crystals will at once be formed without warming. If grape sugar is also present a gentle warming will produce another crop of reddish-yellow crystals. If dextrin be present continued heating will still further augment the number of crystals. Cane sugar and mannite, on the other hand, will respond negatively to this test. The *zymase* of yeasts is capable of fermenting dextrose, levulose and d-mannose forming carbon dioxide and alcohol. Sorbinose is claimed to be non-fermentable.

The disaccharoses having the chemical formula of  $C_{12}H_{22}O_{11}$  include sucrose, maltose, trehalose, melibiose, touranose and agavose. Of these *sucrose* is the most important. It is found in the stems of sugar cane, sorghum, corn and Mexican grass; in many fleshy roots notably the sugar beet; in the sap of the sugar maple and various palms including *Cocos nucifera*, *Phœnix sylvestris*, *Arenga saccharifera*; in various fruits as apples, cherries, figs, etc., in the nectaries of certain flowers; in honey; and in a number of seeds. It crystallizes in monoclinic prisms or pyramids. When sections of plant parts containing cane sugar are placed for a few seconds in a saturated solution of copper sulphate, then quickly rinsed in water, transferred to a solution of 1 part of KOH in 1 part of water, and heated to boiling, the cells containing the sugar take on a sky-blue color. *Invertase* of the yeast reduces cane sugar to dextrose and levulose

and *zymase* of the same plant ferments these forming carbon dioxide and alcohol.

**Maltose** is found in the germinating grains of barley and other cereals as a product of the action of the ferment diastase on starch. It reduces Fehling's solution forming cuprous oxide but one-third less with equal weights.

**Trehalose** or mycose is found in ergot, *Boletus edulis*, the Oriental Trehala and various other fungi.

**Melibiose** is formed with fructose upon hydrolyzing the trisaccharose melitose which occurs in the molasses of sugar manufacture and in Australian manna.

**Touranose** is produced upon hydrolyzing melizitose, a trisaccharose which occurs in Persian manna, and

**Agavose** is found in the cell sap of the American Century Plant, *Agave americana*.

2. **Starch**.—Starch is a carbohydrate having the chemical formula of  $(C_6H_{10}O_5)_n$  which is generally found as the first visible product of photosynthesis in most green plants. It is found in the chloroplasts and chromatophores of green parts in the form of minute granules. This kind of starch is known as **Assimilation Starch**. Assimilation starch is dissolved during darkness within the chloroplasts by the action of ferments and passes into solution as a glucose which is conveyed downward to those parts of the plant requiring food. In its descent some of it is stored up in medullary ray cells, and in various parts of the xylem, phloem, pith and cortex in the form of small grains. Considerable, however, is carried down to the underground parts such as rhizomes, tubers, corms, bulbs or roots where the leucoplasts store it in the form of larger-sized grains called **Reserve Starch**. This type of starch is generally characteristic for the plant in which it is found. It constitutes stored-up food for the plant during that period of the year when the vegetative processes are more or less dormant.

**Structure and Composition of Starch**.—Starch grains vary in shape from spheroidal to oval to chonchoidal to polygonal. They are composed of layers of soluble carbohydrate material and probably other substances called "*lamellæ*" separated from each other by a *colloidal substance* resembling a mucilage in its behavior toward

aniline dyes. They contain a more or less distinct highly refractile point of origin or growth called the "*hilum*," which also takes the stain of an aniline dye. The layers of carbohydrate material stain variously, blue, indigo, purple, etc., with different strengths of iodine solutions. Each grain is covered with a stainable elastic membrane.

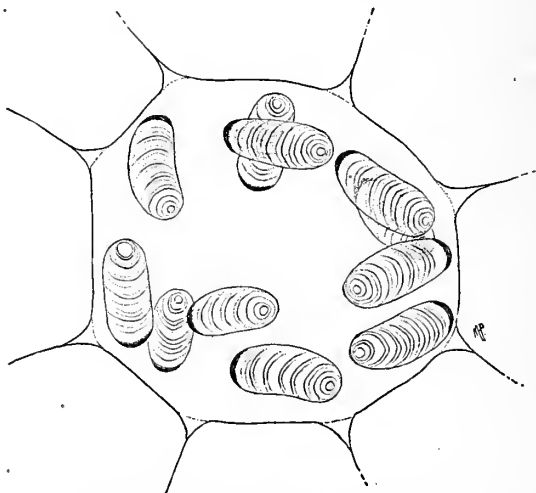


FIG. 15.—Cell of *Pellionia Daveauana*, showing starch-grains. The black, crescent-shaped body on the end of each grain is the *leuoplast*. Greatly enlarged. (Gager.)

Starch grains may be grouped, according to the condition in which they are found in the cells of storage regions into three kinds, viz.: *simple starch grains*, *compound starch grains* and *fill starch grains*.

Simple starch grains are such as occur singly. Compound starch grains occur in groups of two, three, four, five, six or more and are designated as two, three, four, five, six, etc., compound, according to the number of grains making up the group. Fill starch grains are small grains filling up the spaces between the larger grains in storage cells. These are common in commercial starches.

**Method of Examining Reserve Starches.**—Many of the reserve starches are used commercially, such as potato, corn, rice, maranta, oat, wheat, sago, tapioca, etc., and it frequently becomes necessary for the microscopist to determine their purity or their presence in a

sample of food or drug. The following characteristics should be noted in determining the identity or source of the starch.

1. The shape of the grain.
2. Whether simple or compound or both; if compound, the number or range in numbers of grains composing it.
3. The size of the grain in microns.
4. The position of the hilum, if distinct; whether central or eccentric (outside of the center).
5. The shape of the hilum and the degree to which it is often fissured.
6. The nature of the lamellæ, whether distinct or indistinct; if distinct whether concentric (surrounding the hilum) or eccentric (apparently ending in the margin and not surrounding the hilum), or both, as in potato starch.
7. The color of the grains when stained with dilute iodine solutions; whether indigo, blue, purple, red or yellowish-red, etc.
8. The appearance under polarized light.
9. The temperature at which the paste is formed.
10. The consistency of the paste.

#### CHARACTERISTICS OF IMPORTANT COMMERCIAL STARCHES

##### Potato Starch (*Solanum tuberosum*)

Mostly simple, conchoidal or ellipsoidal, with occasional spheroidal and two- to three-compound grains.

Size: 5 to 125 $\mu$

Hilum: circular at smaller end of grain.



FIG. 16.—Potato Starch. ( $\times 250$ )  
(Sayre.)

Lamellæ: concentric and eccentric.  
Polarization cross very distinct;  
beautiful play of colors with  
selenite plate.

##### Maranta Starch (*Maranta arundinacea*)

Ellipsoidal to ovoid.  
Simple.



FIG. 17.—Maranta Starch. ( $+ 250$ )  
(Sayre.)

Size: 10 to  $65\mu$ .

Hilum: a transverse or crescent-shaped cleft in center or near broad end of grain.

Lamellæ: usually indistinct.

Polarization cross very distinct; fine play of colors with selenite plate.

#### Corn Starch (*Zea Mays*)

Polygonal to rounded.

10 to  $35\mu$ . Most grains over  $15\mu$  in diameter.

Simple.



FIG. 18.—Corn Starch. ( $\times 500$ )  
(Sayre.)

Hilum: circular or a two- to five-rayed cleft.

Lamellæ: indistinct.

Polarization cross distinct but no marked play of color with selenite plate.

#### Rice Starch (*Oryza sativa*)

Polygonal.

2 to  $10\mu$  in diameter.

Simple or two- to many-compound.



FIG. 19.—Rice Starch. ( $\times 250$ )  
(Sayre.)

Hilum: usually indistinct, occasionally a central cleft.

Lamellæ: indistinct.

Polarization cross distinct but no play of colors with selenite plate.

#### Wheat Starch (*Triticum sativum*)

Lenticular grains appearing elliptical shaped on edge view; simple.

28 to  $50\mu$  in diameter.

Hilum: central, appearing as dot, usually indistinct.



FIG. 20.—Wheat Starch. ( $\times 250$ )  
(Sayre.)

Lamellæ: indistinct.

Polarization cross indistinct; no play of colors with selenite plate.

#### Rye Starch (*Secale cereale*)

Grains having a similar shape to those of wheat starch but many larger; simple.

20 to  $60\mu$  in diameter.

Hilum: a star-shaped central cleft.

Lamellæ: concentric.

Polarization cross distinct.

#### Buckwheat Starch (*Fagopyrum esculentum*)

Grains simple and compound.

Simple grains polygonal or rounded polygonal.

Compound grains more or less rod-shaped.

2 to  $15\mu$  in diameter.

Hilum: central.

Lamellæ: indistinct.

Polarization cross distinct.

**Cassava Starch** (*Manihot  
utilissima*)

Grains rounded, truncated on one side.

Simple or two- to three- or four- to eight-compound.

6 to  $35\mu$  in diameter.

Hilum: central, circular or triangular with radiating clefts frequently.

Lamellæ: indistinct.

Polarization cross prominent.

**Leguminous Starch**

Ellipsoidal or reniform-shaped simple grains.

50 to  $100\mu$  in length.

Hilum: central, elongated with branching clefts.

Lamellæ: distinct, concentric.

Polarization crosses shaped thus,  $\frac{Y}{X}$

**Canna Starch** (*Canna edulis* and other species of *Canna*)

Broadly elliptical, flattened, with beak or obtuse angle at one end.

50 to  $135\mu$  in length.

Hilum: excentric near narrower end.

Lamellæ: concentric and excentric.

Polarization cross very distinct; fine play of colors with selenite plate.

3. **Inulin.**—Inulin is a carbohydrate isomeric with starch which has the chemical formula of  $C_{12}H_{20}O_{10}$ . It is found dissolved in the cell sap of many plants, especially those of the *Compositæ*. If pieces of a plant part containing this substance be placed directly in alcohol for at least a week, then sectioned and mounted in alcohol, sphærocrystals of inulin will be seen applied to the walls of the cells. When these sections are treated with a 25 per cent. solution of alpha naphthol and 2 or 3 drops of strong  $H_2SO_4$ , the sphærocrystals will dissolve with a violet color. Fehling's solution is not reduced by inulin.

4. **Hesperidin.**—Hesperidin is a glucoside having the chemical formula of  $C_{21}H_{26}O_{12}$ . Like inulin it occurs in solution within the cell sap. It is found in abundance in the *Rutaceæ* family but occurs in many other plants. If sections of alcoholic material containing this substance such as Buchu leaves or unripe orange peel, are mounted in alcohol and examined, sphærocrystals will be seen. If these are then treated with a drop of alpha naphthol solution and 2 or 3 drops of strong  $H_2SO_4$ , they dissolve with a yellow color. The same coloration is evident when 5 per cent. solution of KOH is substituted for the alpha naphthol and  $H_2SO_4$ .

5. **Strophanthin.**—This is a glucoside occurring in the cell sap of the endosperm of *Strophanthus Kombe*, *S. hispidus* and other species of *Strophanthus*. If sections of fresh *Strophanthus* seeds are mounted in a drop of water and then transferred to a drop of con-

concentrated  $H_2SO_4$ , the cells containing strophanthin will assume a bright green color.

6. **Salicin**.—Salicin is a glucoside occurring in the cell sap of the bark and leaves of the Willows and Poplars. Sections of these mounted in concentrated  $H_2SO_4$  will show a red coloration in the cells containing this substance. If water be added a red powder is thrown down.

7. **Saponin**, another glucoside, found in Soap Bark, Senega, Saponaria and other drugs also takes a red color with strong  $H_2SO_4$ .

8. **Coniferin** is a glucoside, occurring in the cell sap of the spruce, pine, and other plants of the *Coniferæ*. If sections containing it are first treated with a solution of phenol and then with sulphuric acid, the cells containing it take on a deep blue color.

8. **Digitoxin**, a glucoside found in the leaves of *Digitalis purpurea*, is colored green with hydrochloric acid.

The *glucosides* are very numerous. Those listed above represent but a few examples. They arise in the cell sap of plants containing them as products of constructive metabolism (anabolism) and are thought by many to have the function of protecting plants against the ravages of animals. Some are known to serve as reserve food. All glucosides are characterized by the property of being split up into glucose and other substances when acted upon by a ferment, dilute acids or alkalies.

9. **Alkaloids**.—Chemically, these are basic carbonaceous amines which like glucosides are products of metabolism. Their method of formation in plants is uncertain. Some hold that they are katabolic products, resulting from the breaking down of tissues, while others believe them anabolic in character. They undoubtedly serve as defensive agents in plants containing them on account of their bitter taste and poisonous properties.

#### *Properties of Alkaloids*

Alkaloids are invariably found in combination with acids forming salts which dissolve in water or alcohol. They are composed of carbon, hydrogen and nitrogen. Some contain oxygen. They are precipitated from saline solutions by the addition of alkalies. They



are mostly colorless and crystallizable. They can be precipitated by one or more of the following alkaloidal reagents: tannic acid, gold chloride, phospho-molybdic acid, picric acid and potassium-mercuric iodide.

### *Examples of Alkaloids*

**Strychnine.**—This alkaloid, with a chemical formula of  $C_{21}H_{22}N_2O_2$ , occurs in the seeds of *Strychnos nux vomica*, *Strychnos Ignatii* and other species of *Strychnos*. When sections of strychnine containing seeds, previously treated with petroleum ether and absolute alcohol, are mounted in a solution of 1 Gm. ammonium vanadate in 100 mls of sulphuric acid, they take on a violet-red color which later changes to brown.

**Veratrine.**—This alkaloid, with a composition of  $C_{37}H_{53}NO_{11}$ , is found in various parenchyma cells of *Veratrum album*. If sections of the rhizome or roots are mounted in 2 drops of water and a drop of concentrated  $H_2SO_4$  and examined microscopically on a glass slide, the cell contents and walls of the *cells* which contain this substance first take a yellow color which soon changes to an orange-red and then to a violet.

**Nicotine.**—This is a volatile alkaloid having the formula of  $C_{10}H_{14}N_2$  which is found in the *Nicotiana* genus of the Nightshade family. Sections of tobacco leaves or stems mounted in dilute Lugol's solution will show first a carmine-red color and then a reddish-brown precipitate which in time loses its color.

**Caffeine.**—This alkaloid, with a formula of  $C_8H_{10}N_4O_2 + H_2O$ , occurs in *Thea*, *Coffea*, *Cola*, *Sterculea*, *Ilex* and *Neea*. If thin sections containing it are placed on a glass slide in 2 or 3 drops of concentrated hydrochloric acid and gently heated and then 2 or 3 drops of gold chloride solution are added, the sections then pushed to the side and the liquid allowed to evaporate, slender yellowish branching needles of caffeine gold chloride will be seen to separate.

**Cocaine.**—This narcotic alkaloid, having the formula  $C_{17}H_{21}NO_4$ , is found in the leaves of *Erythroxylon Coca* and *E. Truxillense*. If sections of these leaves are prepared in the same manner as indicated for those containing Caffeine, but platinum chloride solution substi-

tuted for that of gold chloride, large feathers or plumes of cocaine-chloro-platinate will be seen separating.

**Aconitine** ( $C_{33}H_{43}NO_{12}$ ) is found in various parts of *Aconitum Napellus*. It is particularly abundant in the tuberous root of this plant. If sections of aconite root are treated on a glass slide with solution of potassium permanganate, a red precipitate of aconitine permanganate will appear in the cells containing this alkaloid.

**Colchicine** ( $C_{22}H_{25}NO_6$ ).—This alkaloid occurs in the corm and seeds of *Colchicum autumnale*. It is very abundant in the cells surrounding the fibro-vascular bundles of the corm. If a section of either corm or seed be treated with a mixture of 1 part of  $H_2SO_4$  and 3 parts of  $H_2O$ , the cells containing colchicine will be colored yellow. If a crystal of  $KNO_3$  then be added the color will change to a brownish-violet.

10. **Glucos-alkaloids**.—These are compounds intermediate in nature between alkaloids and glucosides having characteristics of each. To this group belongs solanine ( $C_{28}H_{47}NO_{11}$ ) which is found in *Solanum nigrum*, *Solanum Dulcamara*, *Solanum carolinense* and other species of the *Solanaceæ*. When sections of those plant parts which contain this constituent are mounted in a solution of 1 part of ammonium vanadate in 1000 parts of a mixture of 49 parts of sulphuric acid with 18 parts of water, the cells containing solanin take on a yellow color which changes successively to orange, various shades of red, blue-violet, grayish-blue and then disappears.

11. **Asparagine** ( $C_4H_8N_2 + H_2O$ ).—This is an amino compound of crystalline nature which occurs widely in the plant kingdom. It has been found in certain of the slime molds and fungi, in the roots of *Althæa officinalis* and *Atropa belladonna*, in young shoots of *Asparagus*, in the seeds of *Castanea dentata*, in the tubers of *Solanum tuberosum* and varieties of *Dahlia*, and is known to play an important part in metabolism. Stevens claims that proteids are reduced for the most part to asparagine during seed germination.<sup>1</sup> If thick sections are cut from a plant part containing this substance and mounted in alcohol, rhombohedral crystals of asparagin in the form of plates will be deposited upon the evaporation of the alcohol. If to these a few drops of a saturated solution of asparagine are added

<sup>1</sup>Stevens' Plant Anatomy, 3d Edit., p. 189.

the crystals already formed will increase in size. To get satisfactory results the saturated solution must be of the same temperature as the mount.

12. **Calcium Oxalate.**—This substance occurs in many plants always in the form of crystals. It is apparently formed by the reaction of salts of calcium, which have found their way into the cell sap from the soil, with oxalic acid which is manufactured by the plant. Calcium oxalate crystals dissolve readily in mineral acids without effervescence. They are insoluble in acetic acid or water. These crystals are classified according to form and belong either to the monoclinic or tetragonal system.

*Crystals belonging to the Monoclinic System and Examples of Drugs Containing them:*

1. Solitary—Hyoscyamus, *Acer Spicatum*, *Viburnum Prunifolium*.
2. Rosette Aggregates—Althæa, Gossypii Cortex, Stramonium, Granatum, Rheum, Fœniculum.
3. Columnar (Styloids)—Quillaja.
4. Raphides—Convallaria, Sarsaparilla, Veratrum, Scilla, Phytolacca.
5. Micro-crystals (Crystal sand)—Belladonnæ Radix, Cinchona, Stramonium.
6. Crystal Fibers—Cascara Sagrada, Prunus Virginiana, Glycyrrhiza.
7. Membrane Crystals—Aurantii Dulcis Cortex, Limonis Cortex, Condurango.

*Solitary crystals*, usually in the form of rhombohedra, occasionally in twin crystals, occur as sharp angular bodies each one often completely filling up the lumen of a cell.

*Rosette aggregates* consist of numerous small prisms or pyramids, or hemihedral crystals arranged around a central axis, appearing like a rosette or star.

*Columnar crystals* or styloids are elongated prisms.

*Raphides* are groups of acicular or needle-shaped crystals which occur in long thin-walled cells containing mucilage. They are more frequently found in Monocotyledons than in any other plant group. *Micro-crystals* (sphenoidal micro-crystals or crystal sand) are minute arrow-shaped or deltoid forms completely filling the

parenchyme cells in which they occur and giving these a grayish-black appearance.

*Crystal fibers* are longitudinal rows of superimposed parenchyme cells each of which contains a single monoclinic prism or rosette aggregate. Crystal fibers are found adjacent to sclerenchyme fibers such as bast or woody fibers.

*Membrane crystals* are monoclinic prisms, each of which is surrounded by a wall or membrane. In the process of formation a crystal first is formed in the cell sap and then numerous oil globules make their appearance in the protoplasm surrounding it; later some of the walls of the cell grow around the crystal and completely envelop it.

13. **Cystoliths.**—Cystoliths are clustered bodies formed by the thickening of the cell wall at a certain point and subsequent in-growth which latter forms a cellulose skeleton consisting of a stalk and body. Silica is subsequently deposited on the stalk while calcium carbonate is piled up on the body in layers forming an irregular spheroidal or ellipsoidal deposit. These structures are abundantly found in the plants of the Nettle Family and constitute a leading peculiarity of the same.

Hair cystoliths differ from the average type in that they are devoid of a stalk. Such are seen in the non-glandular hairs of *Cannabis sativa*.

The calcium carbonate incrustation of a cystolith dissolves with effervescence on the addition of a mineral or organic acid.

14. **Silica.**—Silica ( $\text{SiO}_2$ ) occurs in a number of plants either as an incrustation in the cell wall as in Diatoms, the *Equisetineæ* and *Gramineæ* or more rarely in the form "silica bodies" such as are found in certain Palms, Orchids and *Tristicha*. It is insoluble in all the acids except hydrofluoric. It may be obtained in pure form by placing tissue containing it in a drop or two of concentrated sulphuric acid and after a time treating with successively stronger solutions of chromic acid (starting with 25 per cent.) and then washing with water and alcohol.

15. **Tannins.**—Tannins are amorphous substances occurring in plants having an astringent taste, and turning dark blue or green with iron salts. They occur in greatest quantity in the bark of

exogens, and in gall formations. They are soluble in water, alcohol, glycerine, and a mixture of alcohol and ether. They are almost insoluble in absolute ether and chloroform. They give insoluble precipitates with organic bases such as alkaloids and with most of the salts of the heavy metals.

According to their behavior with solution of iron chloride or other soluble iron salts two kinds of tannic acid are recognized: (a) a form of tannic acid giving a blue color, as that which is found in *Rhus*, *Castanea*, *Granatum*, *Galla*, etc.; (b) another tannic acid producing a green coloration, as that found in *Krameria*, *Kino*, *Mangrove bark*, *Quercus*, *Catechu*, etc.

If sections are placed in a 7 per cent. solution of copper acetate for a week or more, then placed on a slide in 0.5 per cent. aqueous solution of ferric chloride, and after a while washed with water and mounted in glycerin, an insoluble brownish precipitate will be produced in those cells containing tannin.

16. **Proteins.**—Proteins are complex nitrogenous substances forming the most important of the reserve foods of plants. They are found in all the living and many of the dead cells of plants although most abundant in seeds. Protoplasm, itself, is composed largely of these substances. They all contain carbon, hydrogen, oxygen, nitrogen and sulphur, and many contain in addition phosphorus. They are formed by the addition of nitrogen, sulphur and frequently phosphorus to elements of grape sugar. The nitrogen, sulphur and phosphorous elements are obtained from nitrates, sulphates and phosphates which are dissolved in the water taken in through the roots. The names of proteins recorded may be found by the hundreds. These are grouped into chemical classes, the most important of which from the standpoint of their occurrence in plants are the *globulins*, *albumens*, *glutelins*, *nucleins*, and *gliadins*. Of these the *globulins* are found most extensively. Globulins are insoluble in water but soluble in sodium chloride solutions. They do not coagulate upon the application of heat.

Albumens are soluble in water and coagulate with heat.

Glutelins are insoluble in water, sodium chloride solution and strong alcohol.

Gliadins are nearly or wholly insoluble in water but soluble in 70 to 90 per cent. alcohol.

Nucleins are insoluble in water but soluble in alkaline solutions.

The following tests are of value in determining the presence of proteins.

Lugol's solution stains proteins yellow or brown.

Concentrated nitric acid stains proteins yellow. This color becomes deeper upon the addition of ammonia water.

Million's reagent stains proteins a brick-red.

Concentrated solution of nickel sulphate colors proteins yellow or blue.

If sections are placed for an hour or two in a solution of 1 Gm. of sodium phospho-molybdate in 90 Gm. of distilled water and 5 Gm. of nitric acid, the proteid substances appear as yellowish granules.

The *globulins* (phytoglobulins) frequently occur in bodies called "aleurone grains."

#### ALEURONE GRAINS

Aleurone grains are small bodies found in seeds particularly those containing oil, and like starch grains often are characteristic of the genus or species. Each aleurone grain consists of a ground substance (composed of amorphous proteid matter soluble in water, dilute alkali or acid), in which are usually embedded one or more *phyto-globulins* (insoluble in cold water, but soluble in less than 1 per cent. solution of an alkali, in dilute HCl and acetic acid), one or more transparent globular *globoids* composed of Ca and Mg phosphate (insoluble in water and dilute potash solution but soluble in 1 per cent. acetic acid solution), and frequently a crystal of *calcium oxalate*, the whole being enclosed by a *protoplasmic membrane* (soluble in water).

The proteins insoluble in the cell-sap water are made soluble for translocation by means of *proteolytic enzymes* which change them into proteoses and peptones.

17. **Mucilages and gums** are those substances occurring in plants which are soluble in water or swell in it, and which are precipitated by alcohol.

Mucilage is formed in plants in several ways, viz.; either as a product of the protoplasm, as a disorganization product of some of the carbohydrates, as a secondary thickening or addition to the cell wall, or as a metamorphosis of it. In the first two cases the mucilage is called *cell-content mucilage*; in the last two, *membrane mucilage*.

Mucilage is stored as reserve food in the tubers of Salep and many other Orchids and also in the seeds of some species of the Leguminosæ.

**Cell-content mucilage** has been found in the leaves of Alœ, the rhizomes of Triticum, the bulb scales of Squill and Onion and in certain cells of many other Monocotyledons especially those containing raphides.

**Membrane mucilage** has been observed in *Barosma*, *Ulmus*, *Allhæa*, *Linum*, *Astragalus*, and *Acacia* species, in the Blue-green Algæ, and many of the Brown and Red Algæ.

When mucilage is collected in the form of an exudate from shrubs and trees it constitutes what is termed a *gum*. Many of these gums are used in pharmacy, medicine and the arts. The three most important from a pharmaceutical standpoint are: **Acacia**, yielded by *Acacia Senegal* and other species of *Acacia*; **Tragacanth**, yielded by *Astragalus gummifer* and other Asiatic species of *Astragalus*; and **Cherry Gum**, obtained from *Prunus Cerasus* and its varieties.

Mucilage may be demonstrated in plant tissues containing it by placing sections of these in a deep blue solution of methylene-blue in equal parts of alcohol, glycerin and water on a glass slide, allowing them to remain in the solution for several minutes, then draining off the stain and mounting in glycerin. Those cells containing mucilage will exhibit bluish contents.

18. **Fixed Oils and Fats.**—These are fatty acid-esters of glycerin which are found in the vacuoles of cells or formed within the cell walls from which they may be liberated as globules upon treating sections with chloral hydrate or sulphuric acid or heating them. They are quite soluble in ether, chloroform, benzol, acetone and volatile oils but insoluble in water and with the exception of castor oil insoluble in alcohol. They are readily distinguished from the volatile oils in that they leave a greasy stain upon paper which does not disappear. Fixed oils and fats take a brownish to black color

with osmic acid, a red color with alkannin or Sudan III and a blue color with cyanin. In *Vaucheria*, the Diatoms and a few of the other *Thallophytes*, fixed oil is formed in the chromatophores instead of starch as the first visible product of photosynthesis. In higher plants it is generally found in storage regions such as the parenchyma seeds, fruits and the medullary ray cells and parenchyma of barks, roots and rhizomes.

19. **Volatile Oils.**—These are volatile odoriferous principles found in various parts of numerous plants which arise either as a direct product of the protoplasm or through a decomposition of a layer of the cell wall which Tschirch designates a “resinogenous layer.” They are readily distilled from plants together with watery vapor, are slightly soluble in water but very soluble in fixed oils, ether, chloroform, glacial acetic acid, naphtha, alcohol, benzin and benzol. They leave a spot on paper which, however, soon disappears. They respond to osmic acid, alkannin, Sudan III, and cyanin stains similar to the fixed oils and fats.

Volatile oils may be grouped into four classes:

A. **Pinenes** or **Terpenes**, containing carbon and hydrogen and having the formula of  $C_{10}H_{16}$ . Examples: Oil of Turpentine and various other volatile oils occurring in coniferous plants.

B. **Oxygenated oils**, containing carbon, hydrogen and oxygen. Examples: Oil of cassia and other cinnamons.

C. **Nitrogenated oils**, containing carbon, hydrogen and oxygen with nitrogen (from HCN). Example: Oil of Bitter Almonds.

D. **Sulphurated oils**, containing carbon, hydrogen and sulphur. Example: Volatile oil of mustard.

20. **Resins, Oleoresins, Gum Resins, and Balsams.**—These substances represent products of metabolism in many plants which are formed either normally as Turpentine, Asafœtida, Mastiche, etc., or as a result of pathological processes through injury to the plant tissues as Styraç, Benzoin, Balsam of Tolu and Peru, etc. They occur usually in special cavities such as secretion cells, glands, or secretion reservoirs.

**Resins** are insoluble in water but mostly soluble in alcohol. They combine with alkalis to form soap. Many of them are oxidized oils of plants. Examples: Guaiacum, Resina.



**Oleoresins** are mixtures of oil and resin. Examples: Terebinthina, Terebinthina Canadensis.

**Gum resins** are natural compounds of resin, gum and oil. Examples: Asafœtida, Myrrha, Cambogia.

**Balsams** are mixtures of resins with cinnamic or benzoic acid or both and generally a volatile oil. Examples: Balsamum Tolutanum, Styrax, Balsamum Peruvianum.

If sections of a resin containing plant part are placed in a saturated aqueous solution of copper acetate for a week or two and mounted in dilute glycerin, the resin will be stained an emerald green.

21. **Pigments.**—These are substances which give color to various plant parts in which they are found. They occur either in special protoplasmic structures as chloroplasts, chromoplasts or chromatophores or, dissolved in the cell sap. Of the pigments named the following will be considered: Chlorophyll, Xanthophyll, Chromophyll, Etiolin, Anthocyanin, Phycocyanin, Phycophæin and Phycoerythrin.

**Chlorophyll** is the yellowish-green pigment found in the chloroplastids or chromatophores of leaves or other green parts of plants. Its composition is not definitely known although it yields products similar to the hæmoglobin of the blood when decomposed. Iron is known to be essential to its formation. If an equal portion of xylene be added to a fresh alcoholic solution of chlorophyll and the mixture shaken, the chlorophyll in solution will break up into a yellowish and greenish portion. The greenish portion dissolves in the xylene which rises forming the upper stratum while the yellowish portion dissolves in the alcohol forming the lower stratum. To this isolated greenish portion of chlorophyll has been given the name of "chlorophyllin" while the yellowish portion has been designated "xanthophyll."

Chlorophyllin when examined spectroscopically produces absorption bands in the red, orange, yellow and green of the spectrum, the broadest and most distinct band being in the red.

**Chromophyll** also called "*xanthophyll*" and "*carotin*" is the yellow or orange pigment found in chromoplastids. By some the term carotin is limited to the orange pigment found in the carrot. Sulphuric acid forms a blue color with chromophyll.

**Etiolin** is a pale yellow pigment which appears when green plants are kept for some time in darkness. It is probably identical with xanthophyll.

**Anthocyanins** are applied to the blue, purple and red pigments which occur in the cell sap. The character of the color is claimed to be due to the alkalinity or acidity of the cell sap.

**Phycocyanin** is the blue pigment found in the blue-green algæ, associated with chlorophyll. It is soluble in water.

**Phycophæin** is the brown pigment found in the brown algæ.

**Phycocerythrin** is the red pigment found in many of the red algæ.

The last two are always associated with chlorophyll but frequently conceal it.

22. **Latex**.—This is an emulsion of varying composition and color found in special passages as latex cells and laticiferous vessels of many plants. It may contain starch, sugar, proteid, oil, enzymes, tannins, alkaloids, gum, resins, caoutchouc and mineral salts. The color may be absent as in *Oleander*; whitish as in *Asclepias*, *Papaver*, *Hevea*, and *Apocynum*; yellowish to orange as in *Celandine*, or red as in *Sanguinaria*.

Chlor-zinc-iodine solution imparts to latex a wine red color.

The latex of the following plants is of value to pharmacy and the arts:

*Papaver somniferum* and its variety *album* which yields **Opium**. That from the unripe capsules is alone used for this drug.

*Palaquium Gutta* which yields **Gutta Percha**.

*Hevea* species, *Ficus elastica*, *Landolphia* species, *Castilloa elastica*, *Hancornia speciosa*, *Forsteronia* species, *Funtumia elastica* and *F. africana*, *Manihot* species, *Clitandra* species and various species of *Euphorbia* furnish most of the **Rubber** of commerce.

*Lactuca virosa* and other species of *Lactuca* yield the drug **Lactucarium**.

23. **Enzymes**.—An *enzyme* or *ferment* (according to Hepburn) is a soluble organic compound of biologic origin functioning as a thermolabile catalyst in solution. Ostwald has defined a catalyst as an agent which alters the rate of a reaction without itself entering into the final product, or which does not appear to take any immediate part in the reaction, remains unaltered at the end of the reac-

tion and can be recovered again from the reaction product unaltered in quantity and quality. The biologic catalysts (enzymes) differ from the inorganic catalysts in that they are sensitive to heat and light. According to Haas and Hill they are destroyed at 100°C. and most of them cannot be heated safely above 60°C. Enzymes are soluble in water, glycerin or dilute saline solutions. They are stimulated to activity by substances known as "activators" and their activity is checked by other substances called "paralyzers." Frequently the paralyzers consist of products of enzyme action. Cold inhibits and warmth accelerates enzyme action. Moisture must always be present for enzymic activity.

### CLASSIFICATION OF ENZYMES

#### A. According to Diffusibility through Cell Wall.

**Endocellular:** Those that cannot diffuse out of the cell. Example: Zymase of Yeast.

**Extracellular:** Those that can diffuse out of the cell. Example: Invertase of Yeast.

#### B. According to Kind of Substances Acted upon and Transformed.

##### 1. Carbohydrate enzymes:

**Diastase** found in the germinating seeds of barley and other grains and in *Aspergillus oryzae*, etc., converts starch to maltose and dextrin.

**Invertase**, secreted by yeasts, and found in younger parts of higher plants, transforms cane sugar, producing dextrose and levulose.

**Maltase**, found in malt and *Saccharomyces octosporus*, transforms maltose to dextrose.

**Trehalase**, found in *Polyporus*, hydrolyzes trehalose to dextrose.

**Cytase**, found in Nux Vomica seeds, in barley, dates, etc., decomposes hemicellulose and cellulose to galactose and mannose.

**Lactase**, found in Kephir grains, hydrolyzes lactose to dextrose and galactose.

**Inulase**, found in Compositaceous plants, transforms inulin to levulose.

**Zymase**, found in yeast, hydrolyzes glucose (dextrose and levulose) to alcohol and carbon dioxide.

## 2. Fat and Oil Ferment:

**Lipase** splits up fats and oils into fatty acids and glycerin. It is found in various mildews, molds and numerous oily seeds and other fatty-oil storage regions of higher plants.

## 3. Proteinaceous Ferments:

**Pepsin** converts proteids into proteoses and peptones.

**Trypsin**, found in yeast, *Boletus edulis*, *Amanita* species, etc., resolves proteins to peptones and amino-acids.

**Bromelin**, found in the fruit of the Pineapple and Papayin (Papain), found in the latex of the fruit of the Papaw, act similarly to trypsin.

**Nepenthin**, found in the pitchers of *Nepenthes* species, acts similarly to pepsin.

## 4. Glucoside Ferments:

**Emulsin** (synaptase), found in the seeds of the Bitter Almond, Cherry Laurel leaves, in the barks of the Wild Black Cherry and Choke Cherry and in other Rosaceous plant parts, in *Manihot utilissima*, *Polygala* species, etc., hydrolyzes the glucoside present (either amygdalin or l-mandelonitrile glucoside) to hydrocyanic acid, benzaldehyde and glucose.

**Myrosin** (myronase), found in the seeds of *Brassica nigra* and other members of the *Cruciferae*, converts the glucoside, Sinigrin, into allyl-iso-sulphocyanide and glucose.

**Rhamnase**, found in *Rhamnus Frangula* and probably other species of *Rhamnus*, hydrolyzes the glucoside frangulin to rhamnose and emodin.

**Gaultherase**, found in *Gaultheria procumbens* and other Ericaceous plants, resolves the glucoside, gaultherin, to methyl-salicylate and glucose.

## CELL WALLS

The cell walls of plants make up the plant skeleton. They are all formed by the living contents of the cells (protoplasts) during cell-divisions. In most plants the cell wall when first formed consists of cellulose,  $(C_6H_{10}O_5)_n$ , a carbohydrate, or closely allied substances. It may remain of such composition or become modified to meet certain

functions required of it. Thus, in the case of outer covering cells as epidermis and cork, whose function is that of protecting the underlying plant units, the walls become infiltrated with cutin and suberin, waxy-like substances, which make them impermeable to water and gases as well as protect them against easy crushing. Again, in the case of stone cells and sclerenchyme fibers whose function is that of giving strength and support to the regions wherein found, the walls become infiltrated with lignin which increases their strength, hardness, and in the case of sclerenchyme fibers, their elasticity also. Moreover, in the case of the cells comprising the testa or outer seed coat of the pumpkin, squash, mustard and flax, etc., whose function is that of imbibing quantities of water, the walls undergo a mucilaginous modification.

**Growth in Area and Thickness.**—The cell wall when first formed is limited in both extent and thickness. As the protoplast within enlarges new particles are placed within the wall by the process called *intussusception*. This increases its area. New particles, also, are deposited on its surface which gradually increases its thickness. The latter process is known as *growth by apposition*.

VARIOUS KINDS OF CELL WALLS AND BEHAVIOR OF EACH TO  
MICRO-CHEMIC REAGENTS

<i>Nature of wall</i>	<i>Where found</i>	<i>Reagent and behavior toward same</i>
Cellulose.....	Parenchyme cells, trichomes such as cotton, etc.	Cuoxam dissolves it. Chlorzinc-iodine solution imparts a blue or violet color. Iodine solution followed by sulphuric acid colors it blue.
Lignocellulose (Lignified wall).	Woody parts of plants, such as stem cells, bast fibers, wood fibers, etc.	Phloroglucin with HCl imparts a red color except to bast fibers of flax. Corallin-soda solution imparts pink color. Aniline sulphate with H <sub>2</sub> SO <sub>4</sub> colors it a golden-yellow. Chlorzinc-iodine imparts a yellow color.
Reserve cellulose	Found in certain seeds such as nux vomica, ivory nut, date, coffee, etc.	As for cellulose.
Mucilaginous modification of cellulose.	In various parts of plants.	Alcoholic or glycerin solution of methylene-blue imparts a blue color.
Suberized walls..	In cork, wounded areas of plants, endodermis.	Alcoholic extract of chlorophyll in the dark imparts a green color. Alcannin and Sudan III impart a red coloration. Converted into yellowish droplets and granular masses upon heating with a strong solution of KOH.
Cutinized walls..	Forming outer walls of many epidermal cells.	As for suberized walls.
Callus of sieve plates.	Plates of sieve tubes.	Corallin-soda solution imparts pink color.
Silicified walls..	Epidermis of Equisetaceæ, Gramineæ, etc.; Diatoms.	Soluble in hydrofluoric acid.

## CHAPTER VI

### PLANT TISSUES

A **tissue** is an aggregation of cells of common source, structure and function in intimate union.

#### THE TISSUES OF SPERMATOPHYTES AND PTERIDOPHYTES

The tissues of seed plants and pteridophytes are all derived from a fertilized egg (oöspore) which has undergone repeated divisions. At first either an apical cell arises or a mass of cells is formed which are essentially alike, but gradually we find that a division of labor has become operative setting aside many different groups of cells, each group of which has its particular rôle to perform in the economy of the whole. Each group of cells similar in source, structure and function is called a tissue. The tissues found in higher plants range from those whose component cells are more or less rounded, in a rapid state of division, and whose thin cellulose cell walls enclose a mass of protoplasm devoid of vacuoles or with exceeding small ones to those whose cells through various physical and chemical factors become compressed, elongated, and highly modified in respect to their contents and walls.

As was shown by Hanstein,<sup>1</sup> the embryo of Angiosperms, while still constituted of only a few cells in the process of division, becomes differentiated into three layers of cells which differ in their arrangement and direction of division; these were called by him, *Dermatogen*, *Periblem* and *Plerome*. In roots a fourth layer of cells is sometimes evident at the apex. This was termed by Janczewski<sup>2</sup> the *Calyptragen* layer. These primary layers or groups of cells are called primary *meristems* or *generative tissues*. They are composed of more or less

<sup>1</sup> Hanstein, "Die Scheitelzellgruppe im Vegetationspunkt der Phanerogamen," Bonn, 1868.

<sup>2</sup> Am. Sci. Nat. 5 série, tom. xx.

rounded cells having delicate cell walls of cellulose which enclose protoplasm and nucleus and wherever found in living embryos are in a rapid state of division.

The generative tissues are found in the growing apices of plant organs such as root, stem and leaf apex. By the division and redivisions of their cells they give rise to the mature or adult tissues of plants.

1. **Dermatogen** originates epidermal tissue and derivative structures such as stomata, non-glandular and glandular hairs, glands, and cork cambium.

2. **Periblem** originates cortex tissue, chlorophylloid cells (chlorenchyma) colloid cells (collenchyma), strengthening cells (sclerenchyma), crystal cells (raphiderchyma) latex cells (lacterchyma), endodermis and cork cambium.

3. **Plerome** originates fibro-vascular bundles, fundamental tissue, pericambium and cambium.

According to structure the following tissues are found in various forms of higher plants:

- |                        |                                     |
|------------------------|-------------------------------------|
| 1. <b>Meristem</b>     | 7. <b>Cork</b>                      |
| 2. <b>Parenchyma</b>   | 8. <b>Laticiferous tissue</b>       |
| 3. <b>Collenchyma</b>  | 9. <b>Cribiform or sieve tissue</b> |
| 4. <b>Sclerenchyma</b> | 10. <b>Tracheary tissue</b>         |
| 5. <b>Epidermis</b>    | 11. <b>Medullary rays</b>           |
| 6. <b>Endodermis</b>   |                                     |

### MERISTEM

**Meristem**, frequently called embryonic tissue, is undifferentiated tissue composed of cells in the state of rapid division. It is found in the growing apices of roots, stems and leaves and is in these regions called *primary meristem*, since it is the first meristem to appear. Such meristem gives rise to the permanent or mature tissues of plants and retains the power of independent growth and capacity for division as long as the plant part survives which contains it. Meristem is also found in other regions of plant organs such as the cambium, cork cambium and pericambium and is there called *secondary meristem*. Secondary meristem loses with its development the power of division and independent growth.



## PARENCHYMA

**Parenchyma** or **Fundamental Tissue** is the soft tissue of plants consisting of cells about equal in length, breadth and thickness (isodiametric) with thin cellulose cell walls enclosing protoplasm and a nucleus and frequently substances of a non-protoplasmic nature. There are four generally recognized types of parenchyma, viz.:

**Ordinary Parenchyma (Soft Ground Tissue, Fundamental Tissue).**

—Next to the meristem this is the least modified of all plant tissues. It is composed of thin-walled cells, commonly polyhedral or spheroidal in form and often of approximately the same length, breadth, and thickness (isodiametric), the cell walls are composed of cellulose which is usually unmodified. Protoplasm and a nucleus are always present, but in old cells are only seen as a thin layer pushed up against the cell wall. Ordinary Parenchyma may be seen composing the soft tissues of roots, stems, and barks.

**Assimilation Parenchyma (Chlorophyll or Chromophyll Parenchyma, Chlorenchyma).**—This form of parenchyma tissue is found in foliage leaves, floral leaves, in the outer region of young green stems and fruits. Its cells are thin walled and vary in shape from more or less isodiametric to irregular and elongated forms. The cells always contain chloroplasts or plastids in whose pores may be found some other coloring substance.

**Conducting Parenchyma.**—This type of parenchyma functions in the rapid translocation of food materials to distant regions in the plant. It includes the *wood parenchyma cells* of the *xylem* which convey a portion of the crude sap (water with mineral salts in solution) and the *phloem parenchyma* (soft bast) which transports the elaborated sap (carbohydrate and proteid material in solution). Conducting parenchyma cells differ from those of ordinary parenchyma in being usually more elongated and in conducting soluble food materials with greater celerity.

**Reserve Parenchyma.**—This resembles ordinary parenchyma in many particulars of structure but differs from it mainly by its cells being filled with starch, protein crystals, or oil globules. It is usually found in seeds, fleshy roots, or underground stems such as tubers, corms, and bulbs.

**Collenchyma.**—This form of tissue is characterized by its cells being prismatic, more elongated than ordinary parenchyma, and thickened in their angles with a colloidal substance. The cells, like those of parenchyma tissue contain protoplasm and a nucleus, and frequently chloroplasts. Collenchyma is generally found underneath the epidermis, and gives strength to that tissue. It is frequently observed forming the “ribs” of stems and fruits of the

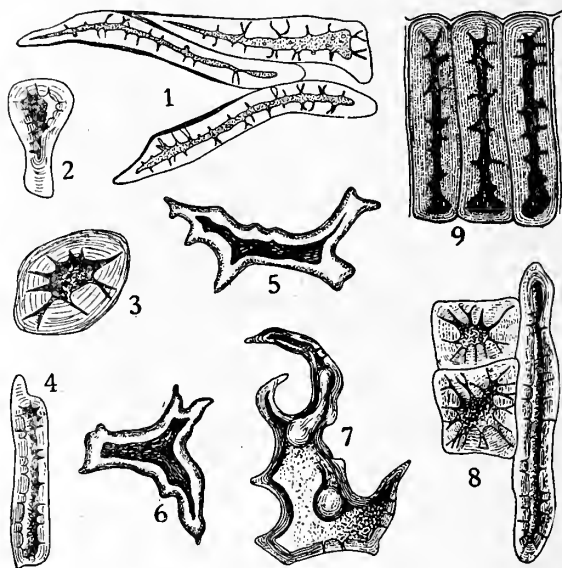


FIG. 21.—Stone cells from different sources. 1. From coffee; 2, 3, and 4, from stem of clove; 5 and 6, from tea leaf; 7, 8, and 9, from powdered star-anise seed. (Stevens, after Moeller.)

*Umbelliferae* and “ribs” of stems of the *Labiatae*. In many leaves it has been found as the supporting and strengthening tissue between the stronger veins and the epidermis.

**Sclerenchyma** or stony tissue comprises a variety of supporting elements having thickened cell walls composed of lignocellulose. When first formed these cells resemble those of ordinary parenchyma in having walls of pure cellulose, but later *lignin* becomes deposited on the inner surface of the walls in one or more layers. (Occasionally as in the rhizomes of Ginger no lignin is deposited on the walls

of the sclerenchyma fibers). When sclerenchyma is composed of cells which are more or less isodiametric or moderately elongated, with thickened lignified walls and conspicuous pores, its elements are called **Stone Cells**. Stone cells are distributed in fruits, seeds and barks of many plants, rarely in woods. They have been found forming the gritty particles in the "flesh" of certain fruits as the Pear, the endocarp or stone region of drupaceous fruits as the Olive, Peach, Cubeb, Pepper, etc., the hard portions of seed coats as in *Physostigma*, Walnuts, etc. Each stone cell presents for examination a cell wall of cellulose with one or several layers of lignin on its inner surface which surround a *central lumen*. The latter is in communication with radial *pore canals* leading outward to the middle lamella. Longitudinal pore canals are also evident.

When sclerenchyma is composed of cells which are greatly elongated and more or less obtusely or taper ended, its component elements are termed **Sclerenchyma fibers**. These fibers are frequently spindle-shaped, contain air and exhibit oblique slits in their walls. They are either polygonal, rectangular or somewhat rounded in transverse section. They occur in various parts of roots, stems, leaves, fruits and seeds as supporting elements. When sclerenchyma fibers occur in the xylem region of fibro-vascular bundles they are termed Wood Fibers; when they appear in the phloem region, *Bast Fibers*.

### EPIDERMIS

**Epidermis** is the outer covering tissue of a plant and is protective in function. Its cells may be brick-shaped, polygonal, equilateral or wavy in outline. Their outer walls are frequently cutinized (infiltrated with a waxy-like substance called cutin). Among the epidermal cells of leaves and young green stems may be found numerous pores or *stomata* (sing. stoma) surrounded by pairs of crescent-shaped cells, called guard cells. The stomata are in direct communication with air chambers beneath them which in turn are in communication with intercellular spaces of the tissue beneath. The function of the stomata is to give off watery vapor and take in or give off carbon dioxide, water and oxygen. In addition to stomata some leaves possess groups of *water stomata* which differ from *trans-*

*piration stomata* in that they always remain open, are circular in outline, give off water in droplets directly, and lie over a quantity of small-celled glandular material which is in connection with one or more fibro-vascular bundles. Examples: Leaves of *Crassula*, *Saxifraga* and *Ficus*.

The epidermis of leaves, stems, fruits, and seeds of many plants frequently give rise to outgrowths in the form of papillæ, hairs and scales. *Epidermal papillæ* are short protuberances of epidermal

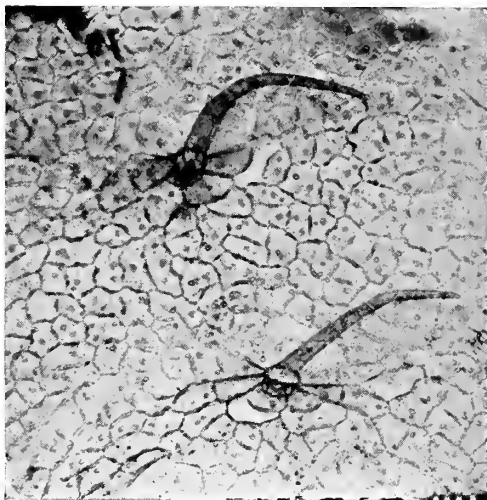


FIG. 22.—Upper epidermis of *Comptonia aspleni folia* leaf (surface view) showing epidermal cells and two non-glandular trichomes.

cells. They may be seen to advantage on the upper epidermis of the ligulate corolla of various species of *Chrysanthemum*, on the lower epidermis of the foliage leaves of species of *Erythroxylon* and upon the upper epidermis of the petals of the Pansy (*Viola tricolor*). **Epidermal hairs** or **trichomes** are more elongated outgrowths of one or more epidermal cells. They may be unicellular (Cotton) or multicellular, non-glandular (simple) or glandular. The *non-glandular* hairs may be of various shapes, viz.: clavate (club-shaped) as on *Rhus glabra* fruits; stellate (or star-shaped) as on *Deutzia* leaves; candelabra-shaped, as on Mullein leaves; filiform as on

Hyoscyamus, Belladonna and Digitalis leaves; hooked, as on stems of *Phaseolus multiflorus* or Hops; barbed, as on the stems of *Loasa* species; or tufted, as found on the leaves of *Marrubium vulgare*. They may be simple as in Cotton, etc., or branched as in *Hyoscyamus muticus*.

The *glandular hairs* comprise those whose terminal cell or cells are modified into a more or less globular gland for gummy, resinous or

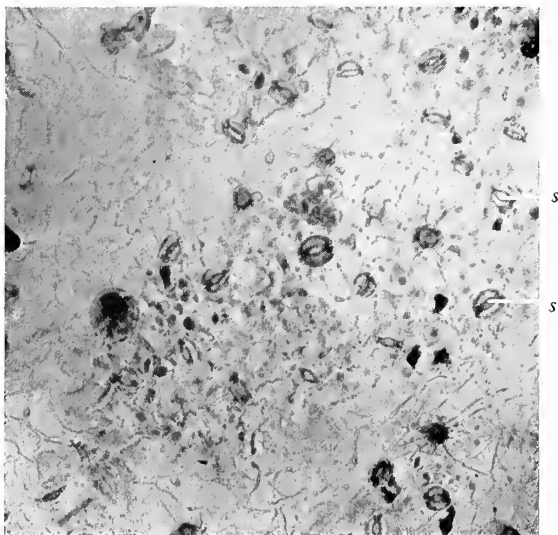


FIG. 23.—Lower epidermis of *Comptonia asplenifolia* leaf (surface view) showing stomata (s) scattered amongst epidermal cells. To the left is to be noted the globular head of a glandular hair. (Photomicrograph).

oily deposits. They are generally composed of a stalk and a head region although rarely the stalk may be absent. The stalk may be unicellular, bicellular or uniseriate (consisting of a series of superimposed cells). The head varies from a one- to many-celled structure. The drug *Lupulin* consists of the glandular hairs separated from the strobiles of *Humulus lupulus*.

**Scales** are flat outgrowths of the epidermis composed of one or several layers of cells. They occur attached to the stipes of *Aspid-*

*ium*, *Osmunda* and other ferns where they are called "chaff scales." They are also found on a number of higher plants.

Plant hairs are adapted to many different purposes. They may absorb nourishment in the form of moisture and mineral matter

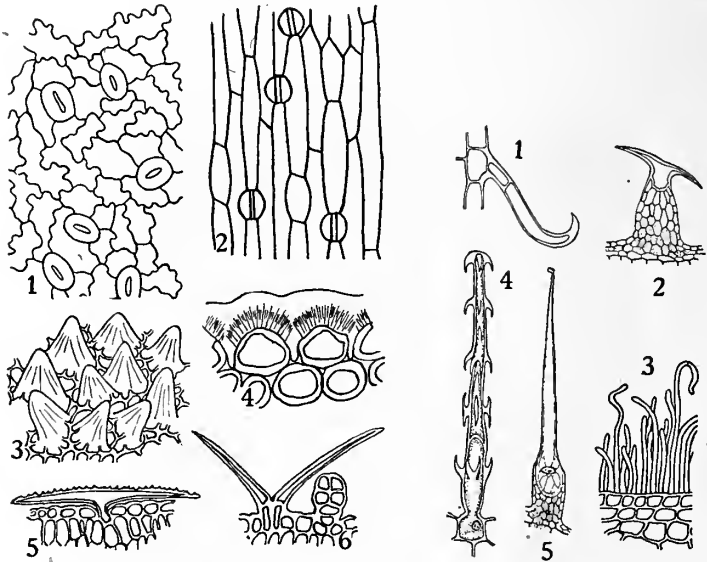


FIG. 24.

FIG. 25.

FIG. 24.—1, Epidermis of oak leaf; 2, epidermis of Iris leaf, both viewed from the surface; 3, group of cells from petal of *Viola tricolor*; 4, two epidermal cells in cross-section showing thickened outer wall differentiated into three layers, namely, an outer cuticle, cutinized layer (shaded), and an inner cellulose layer; 5 and 6, epidermal outgrowths in the form of scales and hairs. (1, 2, 6 after Stevens, 3 after Strasburger, 4 after Sachs, and 5 after de Bary.)

FIG. 25.—Different forms of epidermal outgrowths. 1, Hooked hair from *Phaseolus multiflorus*; 2, climbing hair from stem of *Humulus Lupulus*; 3, rod-like wax coating from the stem of *Saccharum officinarum*; 4, climbing hair of *Loasa hispida*; 5, stinging hair of *Urtica urens*. (Fig. 3 after de Bary; the remainder from Haberlandt.)

in solution, e.g., root hairs. Those which serve as a protection to the plant may be barbed and silicified, rendering them unfit for animal food, or, as in the nettle, charged with an irritating fluid, penetrating the skin when touched, injecting the poison into the wound. A dense covering of hairs also prevents the ravages of insects and the clogging

of the stomata by an accumulation of dust. They fill an important office in the dispersion of seeds and fruits, as with their aid such seeds as those of the milkweed and *Apocynum* are readily scattered by the wind.

The reproductive organs of many Cryptogams are modified hairs, as the sporangia of Ferns.

### ENDODERMIS

**Endodermis** is the "starch sheath" layer of cells, constituting the innermost layer of the cortex. In Angiospermous stems it usually resembles the other parenchyme layers of cortex as to structural characteristics, save that it frequently contains more starch. In fern stems and roots of Angiosperms, however, its cells are clearly distinguished from the other cells of the primary cortex by their elongated form and suberized radial walls. In the roots of Mexican Sarsaparilla the inner as well as the radial walls are suberized; in those of the Honduras variety, inner, radial and outer walls all show suberization. Endodermal tissue is devoid of intercellular air spaces. Its cells contain protoplasm and nucleus. Its functions seem to be to give protection to the stele (tissues within it) and to reduce permeability between primary cortex and stele.

### CORK

**Cork** or suberous tissue is composed of cells of tabular shape, whose walls possess suberized layers. Its cells are mostly filled with air containing a yellow or brownish substance. It is derived from the phellogen or cork cambium which cuts off cork cells outwardly. Cork tissue is devoid of intercellular-air-spaces. It forms a protective covering to the roots of secondary growth, stems (after the first season) of Dicotyledons and Gymnosperms, and wounds of stems and branches. Living cork cells contain protoplasm and cell sap while dead cork cells are filled with air.

### LATICIFEROUS TISSUE

This form of tissue comprises either *latex cells*, *laticiferous vessels*, or *secretory cells* differing from each other in origin and method of development. **Latex cells** are elongated tubes which take their

origin from meristematic cells of the embryo. Elongating with the growth of the plant, they branch in various directions and traverse

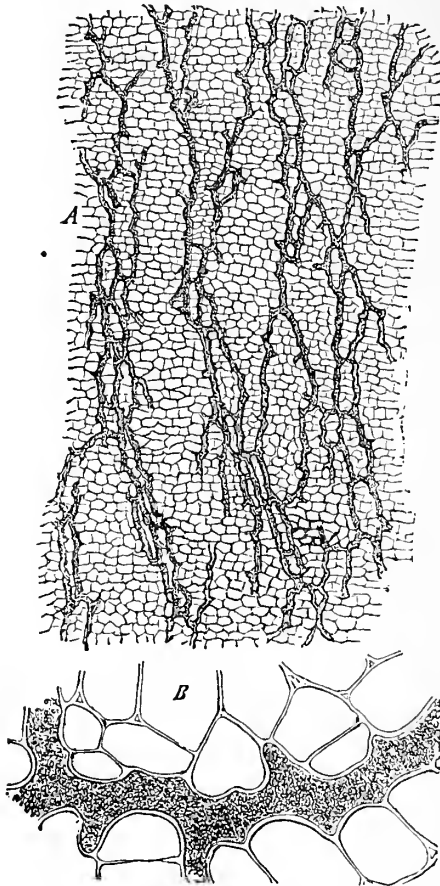


FIG. 26.—Laticiferous vessels from the cortex of root of *Scorozonora hispanica*. A, As seen under low power, and B, a smaller portion under high power. (Stevens, after Sachs.)

at maturity all of its organs. Such cells are abundant in the following families: *Apocynaceæ*, *Asclepiadaceæ*, *Urticaceæ* and *Euphorbiaceæ*.



**Laticiferous vessels** are long simple or branching tubes, which owe their origin to chains of superimposed cells whose transverse walls have early become absorbed, the lumina of the cells then becoming filled with latex. They are found in various parts of roots, stems, and leaves. When branched the branches connect with those of other tubes forming anastomosing network. These vessels occur in the following families: *Compositæ*, *Papaveraceæ*, *Campanulaceæ*, *Convolvulaceæ*, *Euphorbiaceæ*, *Araceæ*, *Oleaceæ*, *Geraniaceæ*, and *Musaceæ*.

Secretory cells with a latex-like content are probably of secondary origin in plants. They resemble in many respects latex cells and are seen in various species of the *Celastraceæ*, *Urticaceæ*, *Tiliaceæ*, and *Oleaceæ* families.

All laticiferous elements contain a colorless, milky-white, or otherwise colored emulsion of gum-resins, fat, wax, caoutchouc and in some cases, alkaloids, tannins, salts, ferments, etc. This emulsion is called "*latex*."

#### SIEVE (LEPTOME OR CRIBIFORM) TISSUE

This tissue found in the phloem (rarely in the xylem) region of fibrovascular bundles consists of superimposed, elongated, tubular cells whose longitudinal walls are thin and composed of cellulose and whose transverse walls, called "*sieve plates*," are perforated, permitting of the passage of proteids from one cell to another. Occasionally sieve plates are formed on the longitudinal walls. Sieve tubes are usually accompanied by companion cells ex-

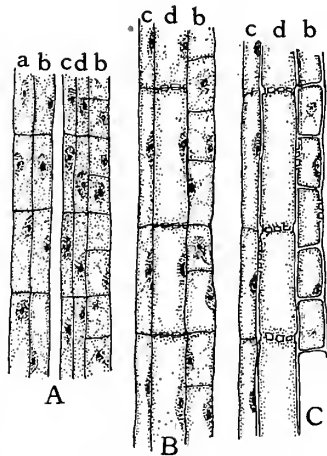


FIG. 27.—Stages in the development of sieve tubes, companion cells, and phloem parenchyma. *A*, *a* and *b*, Two rows of plerome cells; in *c* and *d*, *a* has divided longitudinally and *c* is to become companion cells; *d*, a sieve tube, and *b*, phloem parenchyma. *B*, *c*, Companion cells, and *d*, a beginning sieve tube from *c* and *d*, respectively in *A*. The cross-walls in *d* are pitted; *b*, phloem parenchyma grown larger than in *A*. *C*, The same as *B* with the pits in the cross-walls of the sieve tubes become perforations, and the nuclei gone from the cells composing the tube. (From Stevens.)

cepting in Pteridophytes and Gymnosperms. Both companion cells and sieve tubes arise by the division of the same mother-cell. The companion cells may be distinguished from the sieve tubes by their abundant protoplasmic contents, and also by the fact that they retain their nuclei after complete maturation. Besides sieve tubes, companion cells, and bast fibers, parenchyma cells are often found in the phloem.

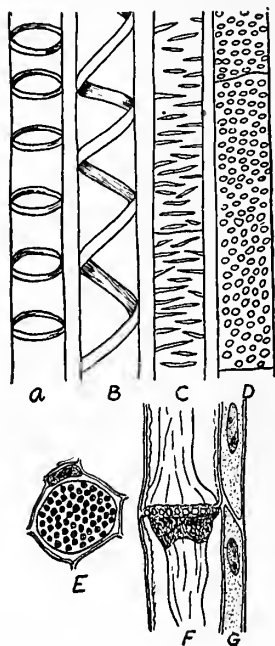


FIG. 28.—Vascular elements. A, annular tracheal tube; B, spiral trachea tube; C, reticulated tracheal tube; D, pitted tracheal tube; E, cross-section through plate of sieve tube, and adjoining companion cell; F, lengthwise section of sieve tube; G, portions of two companion cells. (A, B, C, D, Robbins; E, F, and G, after Strasburger.)

*Reticulate*, with reticulate thickenings.

*Porous* or *pitted* with spherical or oblique slit pores.

*Annulo-spiral*, with both ring and spiral thickenings.

*Scalariform*, with ladder-like thickenings.

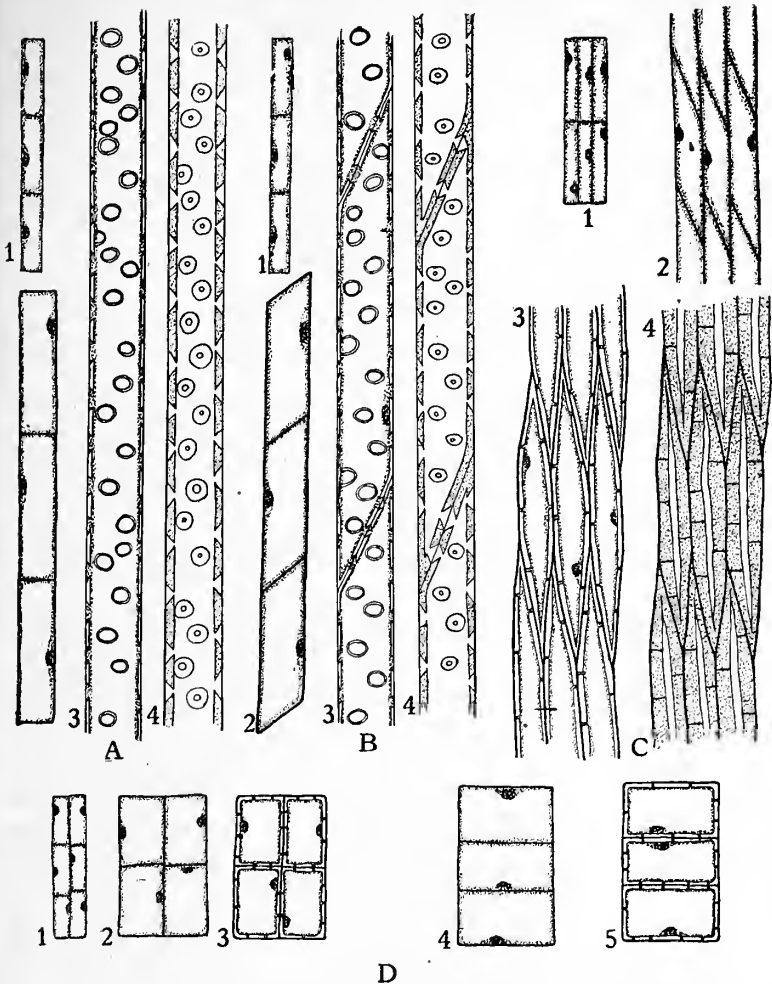
### TRACHEARY TISSUE

The tracheary tissue of plants comprises two kinds of elements, the *tracheæ* (ducts or vessels) and *tracheids*. Both of these conduct *crude sap* (water with mineral salts in solution). The *tracheæ* are very long tubes of a cylindrical or prismatic shape which are formed by the disintegration of the transverse walls between certain groups of superimposed cells, during the growth of the plant. The tubes frequently retain some of their transverse walls. The longitudinal walls of these tubes are of varying thickness, usually, however, thinner than those of woody fibers. The thickness is due to an infiltration of lignin upon the original cellulose wall. The walls show characteristic thickenings on their inner surfaces.

**Tracheæ** are classified according to their markings as follows:

*Annular*, with ring-like thickenings.

*Spiral*, with spiral thickenings.



D

FIG. 29.—Stages in the development of the elements of the xylem. *A*, progressive steps in the development of a tracheal tube. 1, Row of plerome or cambial cells that are to take part in the formation of a tube; 2, the same at a later stage enlarged in all dimensions; 3, the cells in 2 have grown larger, their cross-walls have been dissolved out, and the wall has become thickened and pitted; 4, the walls in 3 have become more thickened, the pits have an overhanging border, the walls have become lignified as indicated by the stippling, and finally the protoplasts have disappeared, and the tube is mature and dead. *B*, Stages in the formation of tracheids from plerome or cambial cells. The steps

**Tracheids** are undeveloped ducts having *bordered pores* and frequently scalariform thickenings. Like tracheæ their walls give the characteristic lignin reaction with phloroglucin and HCl. The

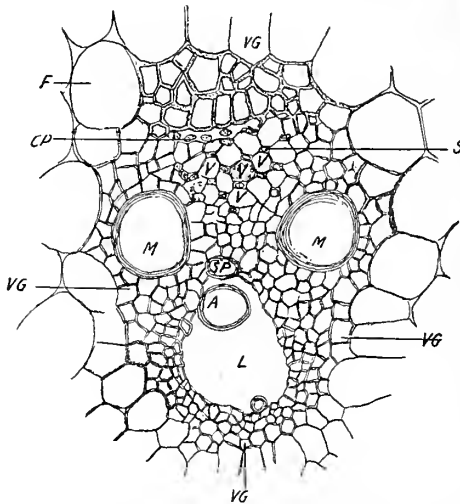


FIG. 30.—Closed collateral bundle of stem of *Zea mays*. VG, Bundle sheath; L, intercellular space; A, ring from an annular tracheal tube; SP, spiral tracheal tube; M, pitted vessels; V, sieve tubes; S, companion cells; CP, crushed primary sieve tubes; F, thin-walled parenchyma of the ground or fundamental tissue. (From Sayre after Strasburger.)

bordered pores exhibit a wall surrounding the pore which forms a dome-shaped protrusion into the cell. Like tracheæ, also, tracheids convey water with mineral salts in solution. Tracheids and medullary rays make up most of the wood of Gymnosperms.

are the same as in A, excepting that the cross-walls remain and become pitted. C, steps in the development of wood fibers from cambial cells. 1, Cambial cells; 2, the same growth larger in all dimensions with cells shoving past each other as they elongate; 3, a later stage with cells longer and more pointed and walls becoming thickened and pitted; 4, complete wood fibers with walls more thickened than in the previous stage and lignified, as shown by the stippling. The protoplasts in this last stage have disappeared and the fibers are dead. D, steps in the formation of wood parenchyma from cambial or procambial cells. 1, Group of cambial or plerome cells; 2, the same enlarged in all dimensions; 3, the same with walls thickened and pitted; 4 and 5 show the same stages as 2 and 3, but here the cells have enlarged radially or tangentially more than they have vertically. The walls of these cells are apt to become lignified, but the cells are longer lived than the wood fibers. (From Stevens.)

## MEDULLARY RAYS

These are bands of parenchyma cells which extend radially from the cortex to the pith (primary medullary rays) or from a part of the xylem to a part of the phloem (secondary medullary rays). Their primary function is to supply the cambium and wood with elaborated sap formed in the leaves and conveyed away by the sieve tubes,

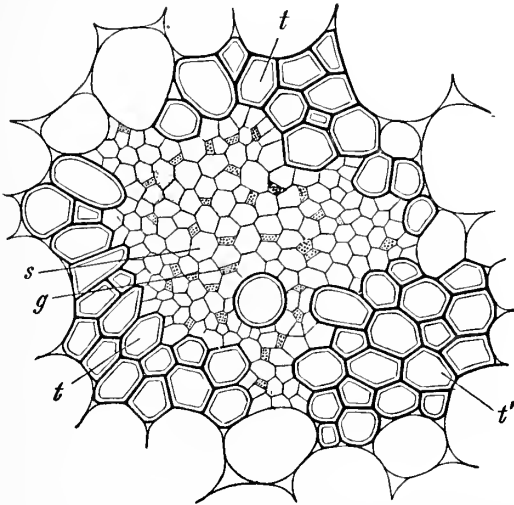


FIG. 31.—Transverse section of a concentric bundle from the rhizome of *Iris* (a monocotyledon). Xylem surrounding the phloem. *t*, Tracheae; *p*, protoxylem; *s*, sieve tubes; *g*, companion cells of the internal phloem portion. (From Sayre after Vines.)

and phloem parenchyma and to supply the cambium and phloem with crude sap which passes up mainly through the tracheae and tracheids from the absorptive regions of the roots. They furthermore serve as storage places for starch, alkaloids, resins, and other substances.

**Fibro-vascular Bundles** are groups of fibers, vessels and cells coursing through the various organs of a plant and serving for conduction and support. According to the relative structural arrangement of their xylem and phloem masses they may be classed as follows:

I. *Closed collateral*, consisting of a mass of xylem lying alongside of a mass of phloem, the xylem facing toward the center, the phloem

facing toward the exterior. Stems of most Monocotyledons and Horsetails.

II. *Open collateral*, consisting of a mass of xylem facing toward the pith and a mass of phloem facing toward the exterior and separated from each other by a cambium. Stems and leaves of Dicotyledons and roots of Dicotyls and Gymnosperms of secondary growth.

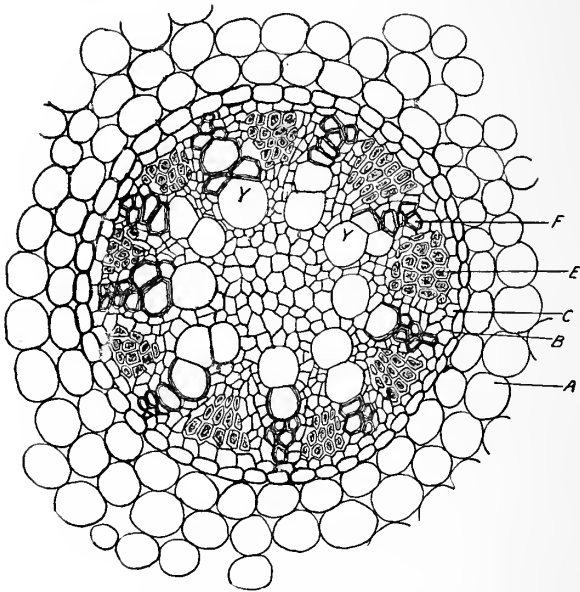


FIG. 32.—Cross-section through a portion of a root of *Acorus calamus*. A. Cortical parenchyma; B, endodermis; C, pericycle; E, phloem; F, xylem. At Y, Y, are large tracheal tubes, which were formed last, the narrow tubes near the periphery of the xylem being formed first. At the center of the root, within the circle of the vascular bundle, occur thin-walled parenchymatous pith cells. (From Sayre after Frank.)

III. *Bicollateral*, characterized by a xylem mass being between an inner and an outer phloem mass. There are two layers of cambium cells, one between the xylem and inner phloem mass, the other between the xylem and outer phloem mass. Seen chiefly in stems and leaves of the *Cucurbitaceæ* and *Solanaceæ*.

IV. *Concentric*, characterized by a central xylem mass surrounded by a phloem mass or *vice versa*. No cambium present.

(a) *Concentric*, with xylem central in bundle. Seen in stems and leaves of nearly all ferns and the *Lycopodiaceæ*.

(b) *Concentric*, with phloem central in bundle. Seen in stems and leaves of some *Monocotyledons*. Examples: Calamus and *Convallaria* rhizomes.

V. *Radial*, characterized by a number of xylem and phloem masses alternating with one another. Seen in the roots of all *Spermatophytes* and *Pteridophytes*.

*Xylem* is that part of a fibro-vascular bundle that contains wood cells and fibers. It may also contain tracheæ, tracheids, seldom sieve tubes.

*Phloem* is that part of a fibro-vascular bundle that contains sieve tubes, phloem cells, and often bast fibers.

#### SECRETION SACS (SECRETION CELLS)

These were formerly parenchyma cells which sooner or later lost their protoplasm and nucleus and became receptacles for oil, resin, oleoresin, mucilage or some other secretory substance. They are generally found in parenchyma regions of stems, roots, leaves, flower or fruit parts and frequently possess suberized walls. Good illustrations of these structures may be seen in Ginger and Calamus.

#### INTERCELLULAR AIR SPACES

Intercellular air spaces are cavities filled with air found between cells or groups of cells throughout the bodies of higher plants. Their function is to permit of the rapid movement of atmospheric gases through the entire plant body. They are formed either by the breaking down of the middle lamella of the cell walls, where several cells come together, and a later separation of the cells at these places (*Schizogenous intercellular air spaces*), or by a breaking down and disappearance of cell walls common to groups of cells (*lysigenous intercellular air spaces*). In terrestrial plants which live in middle regions (*mesophytes*) and in desert plants (*xerophytes*) the intercellular air spaces are averagely small and more or less angular. In plants of swamp or marsh habit they are medium-sized while in those which live entirely in the water (*hydrophytes*) they are of large size and more or less rounded.

## SECRETION RESERVOIRS

These structures are either found as globular or irregular spaces, as in Orange and Lemon Peel and Eucalyptus leaves, containing oil or oil and resin when they are called *internal glands* or, as tube-like spaces filled with hydrocarbon principles such as are found in Pine leaves and stems, when they sometimes receive the name of *secretion canals*. Occasionally they are named according to the nature of their contents—resin or oil canal or reservoir, etc. They are generally lined with a layer of cells, usually more or less flattened, which are characterized by possessing large nuclei. To this layer has been assigned the name “epithelium.”

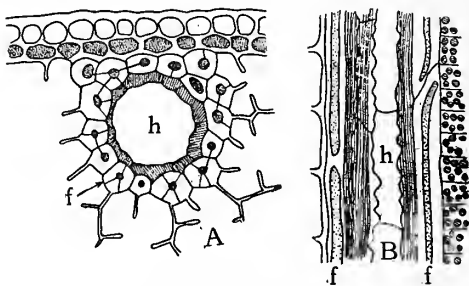


FIG. 33.—Resin duct (secretion reservoir) in leaf of *Pinus silvestris*, in cross section at *A*, and in longitudinal section at *B*; *h*, cavity surrounded by the secreting cells; *f, f*, sclerenchyma fibers surrounding and protecting the duct. (*Stevens, after Haberlandt.*)

**Classification of Tissues According to Function.**—According to their particular function, tissues may be classified as follows:

I. CONDUCTING TISSUE	{	Parenchyme (fundamental tissue)
	{	Xylem cells (wood parenchyme)
	{	Tracheæ (ducts)
	{	Phloem cells
	{	Sieve tubes
	{	Companion cells
II. PROTECTIVE TISSUES	{	Epidermis (outer cell walls cutinized)
	{	Cork (suberized tissue)
III. MECHANICAL TISSUES	{	Bast fibers
	{	Wood fibers
	{	Sclerenchyme fibers
	{	Stone cells



## CHAPTER VII

### PLANT ORGANS AND ORGANISMS

An *organ* is a part of an organism made up of several tissues and capable of performing some special work.

An *organism* is a living entity composed of different organs or parts with functions which are separate, but mutually dependent, and essential to the life of the individual.

The organs of flowering plants are either **Vegetative** or **Reproductive**. The vegetative organs of higher plants are *roots*, *stems*, and *leaves*. They are concerned in the absorption and elaboration of food materials either for tissue-building or storage.

The reproductive organs of higher plants include those structures whose function it is to continue the species, viz.: the *flower*, *fruit* and *seed*.

The ripened seed is the product of reproductive processes, and the starting point in the life of all Spermatophytes. The living part of the seed is the *embryo*, which, when developed, consists of four parts, the *caulicle*, or rudimentary stem, the lower end of which is the beginning of the root, or *radicle*. At the upper extremity of the stem are one, two, or several thickened bodies, closely resembling leaves, known as *cotyledons*, and between these a small bud or *plumule*.

The function of the cotyledon is to build up nourishment for the rudimentary plantlet until it develops true leaves of its own.

#### THE ROOT

The root is that part of the plant that grows into or toward the soil, that never develops leaves, rather rarely produces buds, and whose growing apex is covered by a cap.

The functions of a root are absorption, storage and support. Its principal function is the absorption of nutriment and to this end it

generally has branches or rootlets covered with root-hairs which largely increase the absorbing surface. These root-hairs are of minute and simple structure, being merely elongations of the epidermis of the root back of the root cap into slender tubes with thin walls.

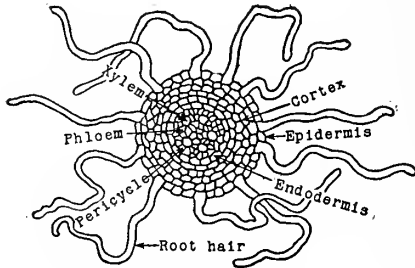


FIG. 34.—Cross-section of rootlet in the region of the root-hairs. (From Stevens.)

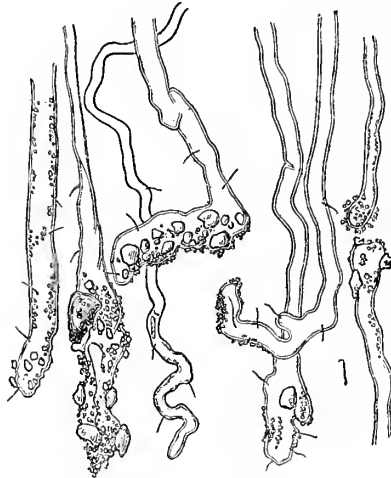


FIG. 35.—Root-hairs, with soil-particles adhering. (Gager, after Sachs.)

The tip of each rootlet is protected by a sheath- or scale-like covering known as the *root cap*, which not only protects the delicate growing point, but serves as a mechanical aid in pushing its way through the soil. The generative tissues in the region of the root cap are: *plerome*, producing fibro-vascular tissue; *periblem*, producing cortex;

*dermatogen*, producing epidermis; and *calyptrogen*, producing the root cap.

### DIFFERENCES BETWEEN ROOT AND STEM

#### *The Root*

1. Descending axis of plant.
2. Growing point sub-apical.
3. Contains no chlorophyll.
4. Branches arranged irregularly.
5. Does not bear leaves or leaf rudiments.
6. Structure comparatively simple.

#### *The Stem*

1. Ascending axis of plant.
2. Growing point apical.
3. Chlorophyll sometimes present.
4. Branches with mathematical regularity.
5. Bears leaves and modifications.
6. Structure better defined.

**Classification of Roots as to Form.**—1. *Primary or first root*, a direct downward growth from the seed, which, if greatly in excess of the lateral roots, is called the *main* or *tap root*. Examples: Taraxacum, Radish.

2. *Secondary roots* are produced by the later growths of the stem, such as are covered with soil and supplied with moisture. Both primary and secondary roots may be either fibrous or fleshy.

The grasses are good examples of plants having fibrous roots. Fleshy roots may be multiple, as those of the Dahlia, or may assume simple forms, as follows:

*Fusiform*, or *spindle-shaped*, like that of the radish or parsnip.

*Napiform* or *turnip-shaped*, somewhat globular and becoming abruptly slender then terminating in a conical tap root, as the roots of the turnip.

*Conical*, having the largest diameter at the base then tapering, as in the Maple.

3. *Anomalous roots* are of irregular or unusual habits, subserving other purposes than the normal.

4. *Adventitious roots* are such as occur in abnormal places on the plant. Examples: Roots developing on Bryophyllum and Begonia leaves when placed in moist sand.

5. *Epiphytic roots*, the roots of epiphytes, common to tropical forests, for example, never reach the soil at all, but cling to the bark of trees and absorb nutriment from the air. Example: Roots of Vanilla.

6. The roots of parasitic plants are known as *Haustoria*. These penetrate the bark of plants upon which they find lodgment, known as hosts, and absorb nutritious juices from them. The *Mistletoe*, *Dodder* and *Gerardia* are typical parasites.

**Duration of Root.**—Plants are classified according to the duration of the root, as follows:

1. *Annual plants* are *herbs* with roots containing no nourishment for future use. They complete their growth, producing flower, fruit and seed in a single season, then die.

2. *Biennial plants* develop but one set of organs the first year, and as in the beet and turnip, etc., a large amount of reserve food material is stored in the root for the support of the plant the following season when it flowers, fruits, and dies.

3. *Perennial plants* live indefinitely, as trees.

**Root Histology.—Monocotyledons.**—The histology of monocotyledonous roots varies, depending upon relations to their surroundings, which may be aquatic, semi-aquatic, mesophytic, or xerophytic. In this connection we will discuss only the type of greatest pharmacognic importance, *i.e.*, the mesophytic type as seen in its most typical form in the transverse section of Honduras Sarsaparilla root.

Examining such a section from periphery toward the center, one notes the following:

1. *Epidermis* of a single layer of cells many of which give rise to root-hairs.

2. *Hypodermis* of two or three layers of cells whose walls are extremely thickened.

3. *Cortex*, consisting of a broad zone of parenchyme cells many of which contain starch grains.

4. *Endodermis* of one layer of endodermal cells whose walls are extremely thickened through the infiltration of suberin and lignin.

5. *Pericambium* of one or two layers of meristematic cells whose walls are extremely thin.

6. A *radial fibro-vascular* bundle of many alternating xylem and phloem patches and hence *polyarch*. The phloem tissue consists of phloem cells and sieve tubes. The xylem is composed of xylem cells, tracheæ and wood fibers.

7. *Medulla* or *pith* composed of parenchyme cells containing starch and often showing xylem patches cut off and enclosed within it.

**Dicotyledons.**—The typical dicotyl root is a tetrarch one, four

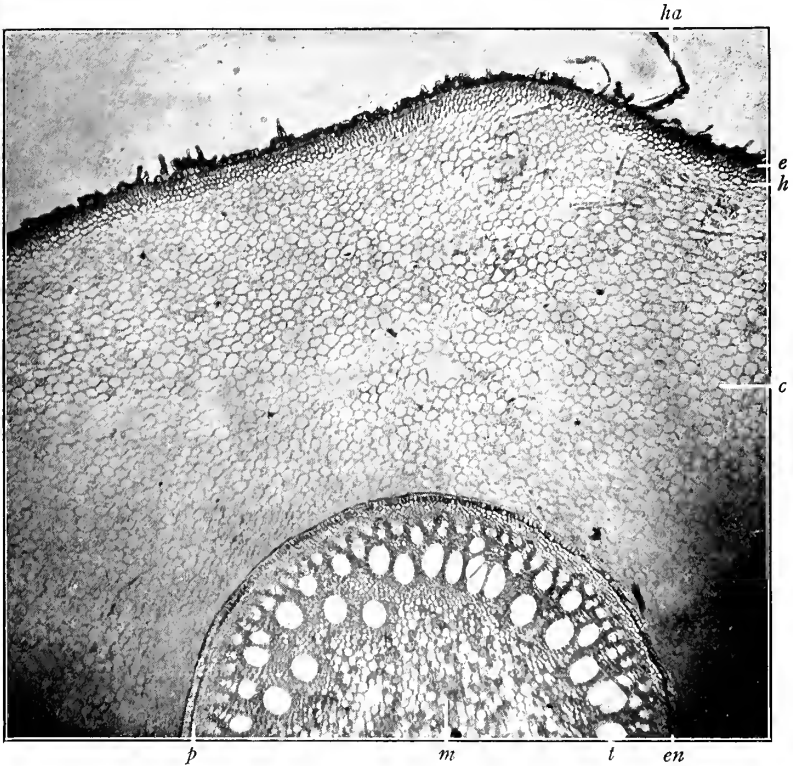


FIG. 36.—Part of a transverse section of Honduras sarsaparilla root showing epidermis (*e*), root hair (*ha*), hypodermis (*h*), cortex (*c*), endodermis (*en*), pericambium (*p*), trachea of one of the numerous xylem patches (*t*), and pith (*m*). The phloem patches are the small oval cellular areas wedged in between the outer portions of adjacent xylem masses. (Photomicrograph.)

xylem alternating with four phloem patches. These roots have an unlimited power of growth.

#### A. Of Primary Growth.

A trans-section of a dicotyl root in its young growth shows the following structure from periphery toward center:

1. Epidermis with cutinized outer walls, the cells often elongating to form root-hairs.
2. Hypodermis.
3. Primary cortex with usually small intercellular spaces.
4. Endodermis, or innermost layer of cells of the cortex with lenticularly thickened radial walls.
5. Pericambium of one to two layers of actively growing cells which may produce side rootlets.
6. Radial fibro-vascular bundle of four, rarely two or three or five or six phloem patches alternating with as many xylem arms. Not uncommon to find bast or phloem fiber along outer face of each phloem patch. Xylem has spiral tracheæ, internal to these a few pitted vessels, then, as root ages, more pitted vessels, also xylem cells and wood fibers make their appearance.

B. *Of Secondary Growth* (Most official roots).

At about six weeks one notes cells dividing by tangential walls in the inner curve of phloem patches. This is intrafascicular cambium. A single layer of flattened cells starts to cut off on its inner side a quantity of secondary xylem and pushes out the patches of bast fibers, adds a little secondary phloem on the outer side. Secondary xylem finally fills up the patches between the arms. The patches of bast fibers get flattened out. The pericambium has a tendency to start division into an inner and outer layer. The outer layer becomes a cork cambium (phellogen) surrounding the bundle inside of the endodermis. It cuts off cork tissue on its outer face, hence all liquid material is prevented from filtering through and cortex including endodermis, as well as the epidermis, shrivel and dry up and separate off at the age of two to three months. The cork cambium (phellogen) may lay down secondary cortex internal to itself and external to the phloem.

Patches of cells of the *inner layer of pericambium* divide rapidly and are called interfascicular cambium. These join the intrafascicular cambium to form a continuous cambium ring which then cuts off additional secondary xylem on its inner face and secondary phloem on its outer face pushing inward the first-formed or protoxylem and outward the first-formed or protophloem. The medullary rays become deepened.

Thus, in a transverse section made through a portion of a Dicotyl root showing *secondary growth*, the following regions are noted passing from periphery to center:

- |                        |   |   |
|------------------------|---|---|
| Fibro-vascular tissue. | } | <ol style="list-style-type: none"> <li>1. Cork</li> <li>2. Cork cambium (phellogen)</li> <li>3. Secondary cortex</li> <li>4. Protophloem</li> <li>5. Secondary phloem</li> <li>6. Cambium</li> <li>7. Secondary xylem</li> <li>8. Protoxylem</li> </ol> |
|------------------------|---|---|

Strands of cells extending radially from the cortex to the center of the section separating each open fibro-vascular bundle from its neighbors. These are called medullary rays.

**Histology and Development of a Dicotyl Root (California Privet).**—A. Make a permanent mount of a T. S. of the root of the California Privet (*Ligustrum Californicum*) cut just above the root cap, and note the following structures, passing from periphery toward the center:

1. Epidermis, composed of a layer of epidermal cells whose outer walls have been infiltrated with a substance called *Cutin*.

2. Hypodermis, a layer of somewhat thick walled cells just beneath the epidermis.

3. Cortex, composed of cortical parenchyme cells with small angular intercellular air spaces.

4. Endodermis, or innermost layer of cells of the cortex, whose radial walls are lenticularly thickened.

5. Pericambium, of a layer of actively growing meristematic cells, which has the power of producing lateral rootlets.

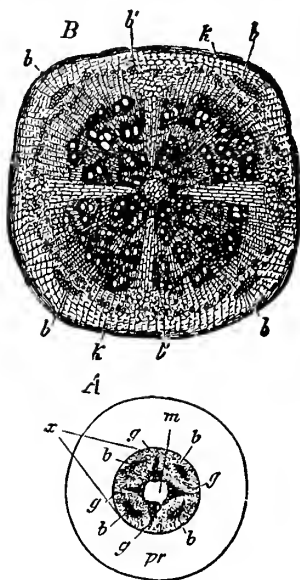


FIG. 37.—Cross-section of a young root of *Phaseolus multiflorus*. A, *pr*, cortex; *m*, pith; *x*, stele or central cylinder—all tissue within the pericycle, inclusive; *g*, primary xylem bundles; *b*, primary phloem bundles. B, cross-section of older portion of root; lettered as in A; *b'*, secondary phloem, *k*, cork. (Stevens, after Vines.)

6. Radial fibro-vascular bundle of five xylem arms alternating with as many phloem patches. Note the narrow spiral tracheæ in the xylem patches.

The section you have just studied illustrated in general the appearance of any Dicotyl root of primary growth.

B. Mount permanently another T. S. cut through the same root a short distance above the first.

Note that this is somewhat larger in diameter. Observe the root hairs starting from the epidermis; a broad cortex; a large clear and open looking endodermis; then pericambium; next, a central patch of xylem showing a faint pentarch relation. Pushed out are five phloem tracts. Each of these constitutes a mass of protophloem (first formed phloem). On the inner face of each phloem mass may be seen intrafascicular cambium. At the outer end of each xylem tract there has been cut off a patch of fine cambial cells (interfascicular cambium) which becomes joined to the intrafascicular cambium to develop secondary phloem on the outer face and secondary xylem on the inner face.

C. Mount permanently a third T. S. out through the same root a short distance above the second. Note that this is still larger in diameter than the second. The pericambium has already divided into an inner and an outer layer. The outer layer has become the cork cambium, cutting off cork on its outer face beneath the endodermis. Cork being an impermeable barrier to water has prevented the nourishing sap from percolating through to the endodermis, cortex and epidermis. The epidermis has consequently begun to sluff off. Note that the cambium has begun to spread out into the form of a ring. More secondary xylem has been formed on its inner face and additional secondary phloem has appeared on its outer face.

D. Make a permanent mount of a fourth T. S. cut through the same root some distance above the third. Note that the epidermis, primary cortex and endodermis have completely peeled off. Cork is found as the external bounding layer and underneath it, cork cambium. This cork cambium has developed secondary cortex on its inner face. The cambium has assumed a circular aspect. Just beneath the secondary cortex will be found flattened patches of protophloem, and beneath these secondary phloem masses have



been formed through the activity of the cambium: The cambium has developed new or secondary xylem on its inner face which has pushed the first formed or protoxylem toward the center of the root.

**Abnormal Structure of Dicotyl Roots.**—In certain Dicotyl roots as *Amaranthus*, *Jalap*, *Pareira*, and *Phytolacca* after the normal bundle system has been formed, there then develop successive cambiums outside of these bundles, producing concentric series of open collateral bundles.

**Histology of a Dicotyl Tuberos Root (*Aconitum*).**—A transverse section made through the tuberos root of *Aconitum Napellus* near its middle shows a cork region of one or more layers of blackish or brownish cells; a broad cortex of two regions, viz.: an outer narrower and an inner broader zone. The narrower zone consists of from eight to fifteen layers of cortical parenchyme cells, interspersed among which are numerous irregular-shaped stone cells. Separating this zone from the broader one is an endodermis of a single layer of tangentially elongated endodermal cells. The broader zone consists of about twenty layers of parenchyme cells. Next, a five- to seven-angled cambium, within the angles of which and frequently scattered along the entire cambial line, occur collateral fibro-vascular bundles. In the center is found a broad five- to seven-rayed pith composed of parenchyme cells. The parenchyme cells of the cortical regions and pith contain single or two- to five-compound starch grains.

#### ROOT TUBERCLES

The roots of plants of the *Leguminosæ*, *Myricaceæ* as well as some species of *Aristolochiaceæ* and of the genera *Alnus* and *Ceanothus* are characterized by the appearance upon them of nodule-like swellings called *root tubercles*. In the case of the *Leguminosæ* the causative factor is a species of bacteria named *Pseudomonas radicola*. This is a motile rod-shaped organism which appears widely distributed in soils. It is apparently attracted to the root-hairs of leguminous plants by a chemotactic influence probably due to the secretions poured out by these structures. A number of these organisms penetrate the walls of the root-hairs by enzymic action. Upon entering the hairs they form *bacterial tubes* which branch and rebranch and

extend into the middle cortex cells carrying the bacteria with them. Within the cortex cells the organisms multiply rapidly producing nest-like aggregations. Their presence here causes the formation of nodules or tubercles. Under oil-immersion magnification these bacteria are found to exhibit variously shaped involution forms called *bacterioids*. They remain within the cells of the medio-cortex region

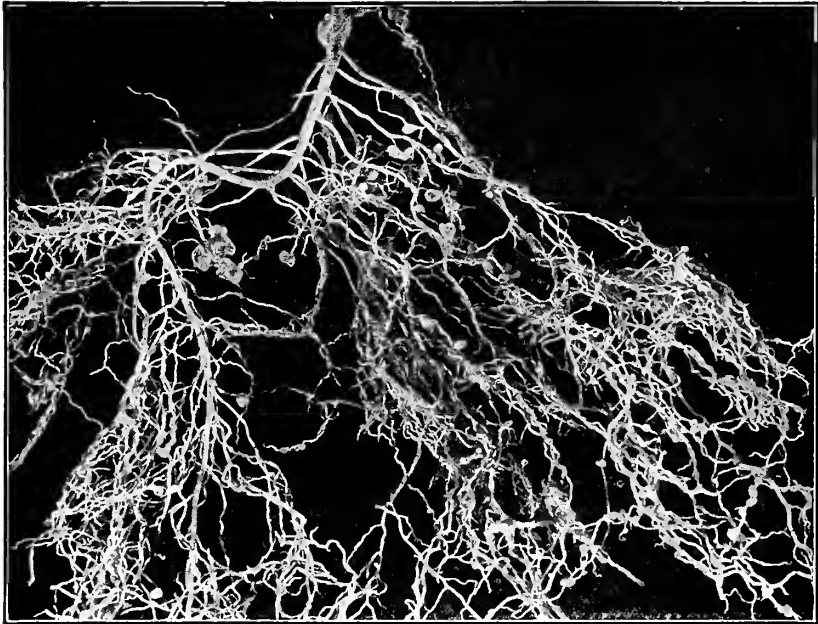


FIG. 38.—Root system of a legume showing tubercles. (Marshall.)

gradually swelling up into *zoöglæa* masses until finally their bodies break down into soluble nitrogenous substances which are partly absorbed and assimilated and partly stored as reserve nitrogenous food for the green leguminous plant.

In the modern rotation of crops, plant growers plough under the leguminous crops or their nodule-producing roots which decay and enrich the soil with ample nitrogenous material to supply the next season's crop of nitrogen-consuming plants.

The writer has found tubercles on *Myrica cerifera*, *Myrica Caroliniensis* and *Myrica Macfarlanei* seedling primary roots of 5 to 6 months' growth, and from thence onward on the secondary roots inserted on the hypocotyl axis, on nearly all the adventitious roots of subterranean branches and on the subterranean branches of *Myrica cerifera*, *M. Caroliniensis*, *M. Gale*, *M. Macfarlanei*, and *Comptonia asplenifolia*. The inciting organism has been isolated by him in pure culture according to Koch's postulates and named *Actinomyces Myricarum* Youngken.

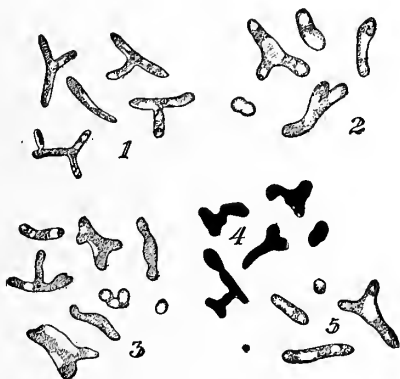


FIG. 39.—*Ps. radicolica*. 1, From *Melilotus alba*; 2 and 3, from *Medicago sativa*; 4, from *Vicia villosa*. (Marshall, after Harrison and Barlow from Lipman.)

The tubercles occur either singly, as is frequently the case on subterranean branches, in small groups the size of a pea, or in larger coralloid loose or compact clusters which frequently attain the size of a black walnut. Each tubercle is a short cylindrical blunt-ended root-like structure which branches di- or trichotomously after attaining a certain length. The branches frequently rebranch at their tips which grow out into long thread-like structures from 1-3 cm. in length that may also branch and become entwined about the roots of other plants. The color of the youngest tubercles is a pinkish-gray brown. As the tubercles become older their color changes to brown, dark-brown and even black. (For a detailed description of the *Myrica* and *Comptonia* tubercles and their inciting organism, con-

sult, "The Comparative Morphology, Taxonomy and Distribution of the Myricaceæ of the Eastern United States" by Youngken in U. of Pa. Library.)



FIG. 40.—Tubercular clusters on underground stem and roots of *Myrica Macfarlanei* observed by the author at North Wildwood, N. J., Jan. 31, 1915.

## THE BUD

Buds are short young shoots with or without rudimentary leaves (bud scales) compactly arranged upon them.

The *plumule* represents the first bud on the initial stem or caulicle.

*Scaly buds* are such as have their outer leaf rudiments transformed into scales; there are often coated with a waxy or resinous substance without and a downy lining within, to protect them from sudden changes in climate. Buds of this character are common among shrubs and trees of temperate regions.

*Naked buds* are those which are devoid of protective scales. They are common to herbaceous plants.

*Classification of Buds According to Development.*—1. A *leaf bud* is a young shortened shoot bearing a number of small leaves. It is capable of elongating into a branch which bears leaves.

2. A *flower bud* is a rudimentary shoot bearing one or more concealed and unexpanded young flowers.

3. A *mixed bud* is a young shoot bearing concealed unexpanded leaves and flowers.

*Classification of Buds According to Position on the Stem.*—1. A *terminal bud* is one which is located on the end of a stem (shoot). It is capable of elongating into a shoot which bears leaves or both leaves and flowers.

2. An *axillary* or *lateral bud* is one which arises in the leaf axil. It is capable of giving rise to a side branch or to a flower. Occasionally axillary buds do not develop and are then called *dormant buds*.

3. An *adventitious bud* is one which occurs on some position of the stem other than at its apex or in the axil of a leaf. Such buds may be seen developing along the veins of a Begonia leaf or along the margin of a Bryophyllum leaf after these have been planted in moist soil for several days.

4. An *accessory bud* is an extra bud which forms in or near the leaf axil.

*Classification of Buds According to Their Arrangement on the Stem.*

1. When a single bud is found at each joint or *node* of a stem, the buds are said to be *alternate*.

2. When two buds are found at a node they are *opposite*.

3. When several buds occur at a node they are *whorled*.

## THE STEM

The stem is that part of the plant axis which bears leaves or modifications of leaves and its branches are usually arranged with mathematical regularity.

Stems usually grow toward the light and so are heliotropic.

The functions of a stem are to bear leaves or branches, connect roots with leaves, and conduct sap.

When the stem rises above ground and is apparent, the plant is said to be *caulescent*.

When no stem is visible, but only flower or leaf stalks, the plant is said to be *acaulescent*.

Stems vary in size from scarcely  $\frac{1}{25}$  inch in length, as in certain mosses, to a remarkable height of 400 feet or more. The giant Sequoia of California attains the height of 420 feet. Some of the Eucalyptus trees of Australia and Tasmania are reported to attain the height of 500 feet.

**Nodes and Internodes.**—The nodes are the joints of stems. They represent the parts of the stem from which leaves or branches arise. Internodes are the parts of stems between nodes.

**Direction of Stem Growth.**—Generally the growth of the stem is erect. Very frequently it may be:

*Ascending*, or rising obliquely upward. Example: Saw Palmetto.

*Reclining*, or at first erect but afterward bending over and trailing upon the ground. Example: Raspberry.

*Procumbent*, lying wholly upon the ground. Example: Pipsissewa.

*Decumbent*, when the stem trails and the apex curves upward. Example: Vines of the Cucurbitaceæ.

*Repent*, creeping upon the ground and rooting at the nodes, as the Strawberry.

**Stem Elongation.**—At the tip of the stem there is found a group of very actively dividing cells (meristem) which is the growing point of the stem. All the tissues of the stem are derived from the cells of the growing point whose activity gives rise in time to three generative regions which are from without, inward:

1. *Dermatogen*, forming epidermis;
2. *Periblem*, forming the cortex; and
3. *Plerome*, forming the fibro-vascular elements and pith.

**Duration of Stems.**

*Annual*, the stem of an herb whose life terminates with the season. Example: Corn.

*Biennial*, where the stem dies at the end of the second year. Example: Burdock.

*Perennial*, when the stem lives for many years. Example: Oak.

**Stem Modifications.**—(1) twining, by elongation and marked circumnutation of young internodes as in *Convolvulus*, *Dodder*,

etc. (2) Tendriliform by thread-like modification and sensitivity to contact of a side branch as in Passion flower, Squash, etc. (3) Spiny, by checking and hardening of a branch that may then become defensive ecologically as in hawthorn, honey locust, etc. (4) Aerial tuberous, in which one or more internodes enlarge above ground and store reserve food as in pseudobulbs of orchids, *Vitis gongyloides*, etc. (5) Subterranean tuberous in which a subterranean stem or branch enlarges as a food-storing center: (a) annual type, tuber as in potato, etc., corm as in crocus, etc.; (b) perennial type, bulbs as in lily (scaly) and onion or hyacinth (tunicated). (6) Phylloid or leaf-like in which flattening branch expansion occurs, when leaves become reduced in size as in Asparagus, Ruscus, etc.. (7) Cactoid, in which reduced condensed branches or stems become swollen for water (and food) storage as in Cacti, *Euphorbia* sp., etc.

**Above-ground Stems.**—A *twining* stem winds around a support, as the stem of a bean or Morning Glory.

A *culm* is a jointed stem of the Grasses and Sedges.

A *climbing* or scandent stem grows upward by attaching itself to some support by means of aerial rootlets, tendrils or petioles. Examples: Ivy, Grape, etc.

The *scape* is a stem rising from the ground and bearing flowers but no leaves, as the dandelion, violet, or blood root.

A *tendril* is a modification of some special organ, as of a leaf stipule or branch, capable of coiling spirally and used by a plant in climbing. Present in the Grape, Pea, etc.

A *spine* or thorn is the indurated termination of a stem tapering to a point, as the thorns of the Honey Locust.

*Prickles* are outgrowths of the epidermis and cortex and are seen in the roses.

A *stolon* is a prostrate branch, the end of which, on coming in contact with the soil, takes root, so giving rise to a new plant. Examples: Currant and Raspberry.

An *herbaceous stem* is one which is soft in texture and readily broken. Example: *Convallaria*.

An *undershrub* or *suffruticose* stem is a stem of small size and woody only at the base. Examples: Bitter-sweet, Thyme, etc.

A *shrubby* or *fruitcose* stem is a woody stem larger than the preceding and freely branching near the ground. Example: Lilac, etc.

A *trunk* is the woody main stem of a tree.

## HERB AND TREE

A *tree* is a perennial woody plant of considerable size (20 feet or more in height) and having as the above-ground parts a trunk and a crown of leafy branches.

An *herb* is a plant whose stem does not become woody and permanent, but dies, at least down to the ground, after flowering.

**Underground Stems.**—A *rhizome* is a creeping underground stem, more or less scaly, sending off roots from its lower surface and stems from its upper. The rhizome grows horizontally, vertically or obliquely, bearing a terminal bud at its tip. Its upper surface is marked with the scars of the bases of aerial stems of previous years. Examples: Triticum, Rhubarb, etc.

The *tuber* is a short and excessively thickened underground stem, borne usually at the end of a slender, creeping branch, and having numerous eyes or buds. Example: Tubers of the Potato.

The *corm* is an underground stem excessively thickened and solid and characterized by the production of buds from the center of the upper surface and rootlets from the lower surface. Examples: Colchicum, Jack-in-the-Pulpit, etc.

A *bulb* is a very short and scaly stem, producing roots from the lower face and leaves and flower from the upper.

*Tunicated bulbs* are completely covered by broad scales which form concentric coatings. Examples: Onion, Squill, Daffodil.

*Scaly bulbs* have narrow imbricated scales, the outer ones not enclosing the inner. Example: Lily.

*Tubers and corms* are annual. *Bulbs and Rhizomes* are perennial.

**Exogenous and Endogenous Stems.**—*Exogenous stems* are typical of Gymnosperms and Dicotyledons and can increase materially in thickness due to presence of a cambium. Such stems show differentiation into an outer or cortical region and an inner or central cylinder region.

*Endogenous stems* are typical of most Monocotyledons and cannot



increase materially in thickness due to absence of cambium. The limited increase in diameter that does take place is due to the enlargement of the cells of the primary tissues. Such stems show no differentiation into cortical and central regions.

**Histology of Annual Dicotyl Stem.**—(In both annual and perennial dicotyledonous stems endodermis and pericambium are rarely seen

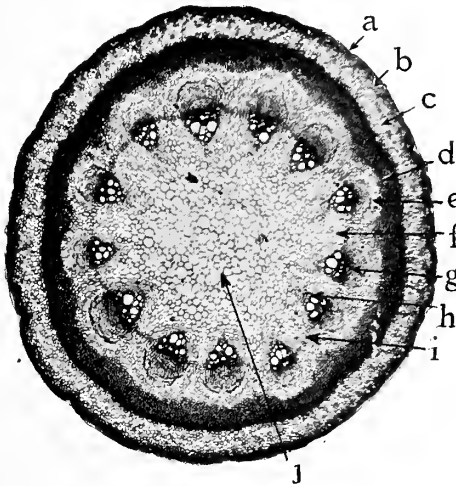


FIG. 41.—Photomicrograph of cross-section of stem of *Aristolochia sipo*, where cambial activity is just beginning. *a*, Epidermis; *b*, collenchyma; *c*, thin-walled parenchyma of the cortex, the innermost cell layer of which is the starch sheath or endodermis; *d*, sclerenchyma ring of the pericycle; *e*, thin-walled parenchyma of the pericycle; *f*, primary medullary ray; *g*, phloem; *h*, xylem; *i*, interfascicular cambium; *j*, medulla or pith.  $\times 20$ . (From Stevens.)

since each has become so similar to cortex through passage of food, etc.)

1. Epidermis, cutinized, with hairs.
2. Cortex composed of three zones: an outer or exocortex, whose cells are thin walled and contain chloroplasts; a middle or medio-cortex, consisting of cells of indurated walls giving extreme pliability and strength, an inner or endocortex, a very broad zone of thin- and thickened-walled parenchyma cells.
3. The innermost layer of cells of the cortex called endodermis. (Not generally distinguishable.)

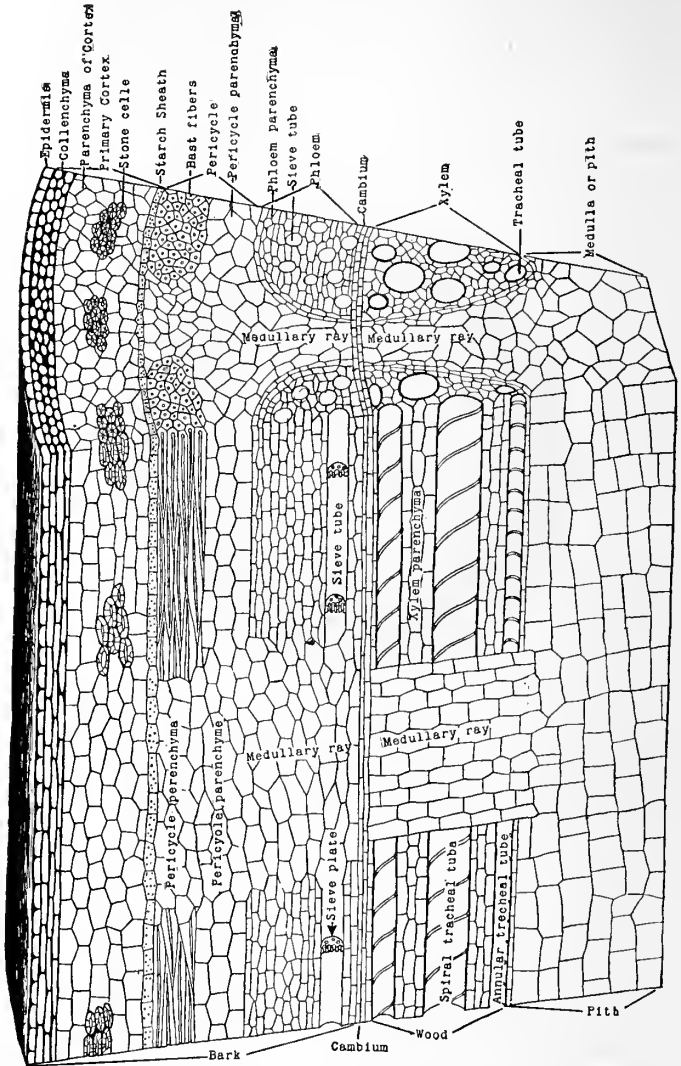


FIG. 42.—A diagram to show the character of the tissues and their disposition in a young stem of the typical dicotyledon type. (From Stevens.)

4. Pericambium. (Not generally distinguishable.)
5. Fibro-vascular bundles of open collateral type arranged in a circle with primary medullary rays between the bundles.
6. Pith.

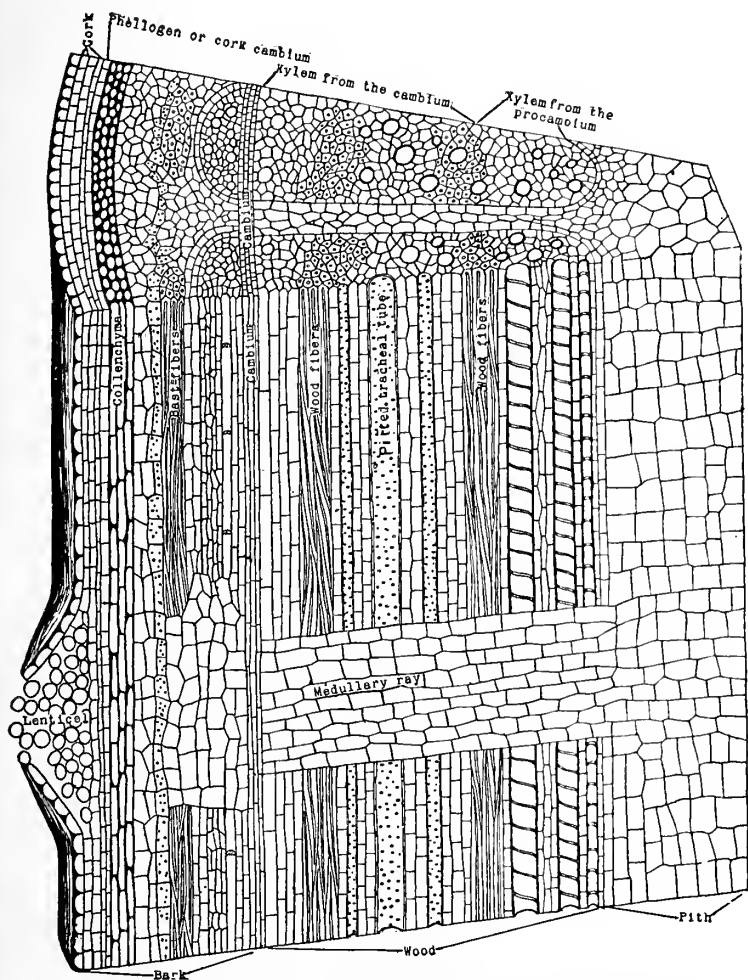


FIG. 43.—Diagram similar to the preceding but representing a later stage and showing the tissues formed by the cambium. (From Stevens.)

**Growth of Perennial Dicotyl Stem and its Histology.**—A perennial dicotyl stem in the first year does not differ in structure from an annual. By the close of the year a cork cambium (phellogen) has originated beside the epidermis. In origin of cork cambium—one of two methods: (a) either the epidermis may divide into an outer layer of cells that remains epidermis and an inner layer of cells that becomes cork cambium, or, (b) the outermost layer of cortex cells underneath the epidermis becomes active after being passive for one year, and lays down walls, the inner layer becoming cork cambium, the outer becoming a layer of cork. The cork cuts off water and food supplies from epidermis outside and so epidermis separates and falls off as a stringy layer. The cork cambium produces cork on its outer face and secondary cortex on its inner.

Between the bundles certain cells of the primary medullary rays become very active and form interfascicular cambium which joins the cambium of the first-formed bundles (intrafascicular cambium) to form a complete cambium ring. By the rapid multiplication of these cambial cells new (secondary) xylem is cut off internally and new (secondary) phloem externally, pushing inward the first-formed, or *protoxylem*, and outward the first-formed, or *proto-phloem*, thus increasing the diameter of the stem. The primary medullary rays are deepened. Cambium may also give rise to secondary medullary rays.

Sometimes, as in Grape Vines, Honeysuckles, and Asclepias, instead of cork cambium arising from outer cortex cells it may arise at any point in cortex. It is the origin of cork cambium at varying depths that causes extensive sheets of tissue to separate off. That is what gives the stringy appearance to the stems of climbers.

At close of first year in *Perennial Dicotyl Stem* we note:

Periblem development

1. Epidermis—development of dermatogen or periblem—in process of peeling off, later on entirely absent.
2. Cork tissue or periderm.
3. Cork cambium or phellogen.
4. Sometimes zone of thin-walled cells containing chloroplasts cut off by cork cambium on inner face and known as phelloderm.
5. Cortex—in perennial stem cells of cortex *may* undergo modification into mucilage cells, into tannin receptacles, crystal cells, spiral cells, etc.

6. Fibro-vascular bundles of open collateral type which are now arranged into a compact circle, and between which are found primary and often secondary medullary rays.

From without inward the following tissues make up f. v. bundles.

Protophloem { Hard Bast—long tenacious bast fibers.

Secondary Phloem { Soft Bast—phloem cells and sieve tubes.

Cambium—active layer giving rise to secondary phloem on outer and secondary xylem or inner face, and adding to depth of med. rays.

Secondary xylem—wood fibers, pitted vessels, tracheids.

Protoxylem—spiral tracheæ.

Pith.

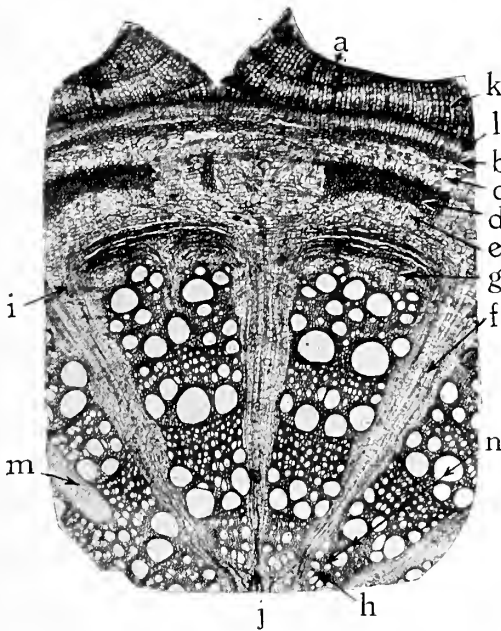


FIG. 44.—Portion of cross-section of four-year-old stem of *Aristolochia siphon*, as shown by the rings of growth in the wood. The letters are the same as in Fig. 41 but new tissues have been added by the activity of the cambium; and a cork cambium has arisen from the outermost collenchyma cells and given rise to cork. The new tissues are; *l*, cork cambium; *k*, cork; *g*, secondary phloem from the cambium, and just outside this is older crushed phloem; *n*, secondary xylem produced by the cambium; *m*, secondary medullary ray made by the cambium (notice that this does not extend to the pith). Half of the pith is shown. Notice how it has been crushed almost out of existence. Compare Figs. 41 and 44, tissue for tissue, to find out what changes the primary tissues undergo with age, and to what extent new tissues are added. Photomicrograph  $\times 20$ . (From Stevens.)

## EXCEPTIONAL TYPES OF DICOTYL STEMS

In a number of Dicotyledons and Gymnosperms, the secondary growth in thickness of the stem and frequently of the root differs from that which is found in the vast majority of species and so is called exceptional or anomalous.

In *Phytolacca*, etc., there first arises a ring of primary bundles with broad loose medullary rays. Then the stem cambium ceases its



FIG. 45.—White birch (*Betula populifolia*). Portion of a branch showing the prominent lenticels. (Gager.)

activity and, outside the bast of the bundles already formed in the pericambium or tissue developing from it, a new cambium starts to lay down another ring of bundles in rather irregular fashion. Then after developing a wavy ring of bundles and connecting tissue that cambium closes up. Still another cambium ring arises without this, and in a single season quite a number of these are found successively arranged in concentric fashion.

In *Gelsemium*, species of *Solanaceæ*, *Combrétacæ*, *Cucurbitacæ*, etc., there arises a cambium on the inner face of the xylem which

forms *internal phloem* (or *intra-xylary phloem*), thus giving rise to bicollateral bundles.

In *Strychnos Nux Vomica* internal phloem exactly as in *Gelsemium*, etc., appears but in addition *interxylary phloem* is developed. In the wood region of this plant axis the cambium starts at a certain age to lay down patches of phloem which become wedged in between xylem tissue as interxylary phloem.

**Lenticels and Their Formation.**—The epidermis in a great majority of cases produces stomata, apertures, surrounded by a pair of guard cells, which function as passages for gases and watery vapor from and to the active cells of the cortex beneath.

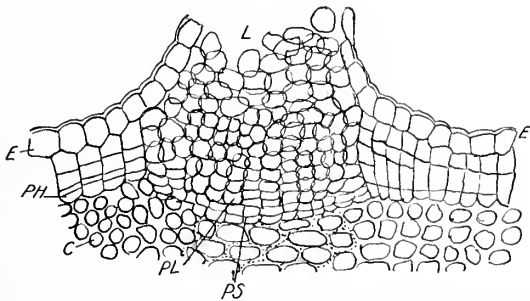


FIG. 46.—Cross-section through a lenticel of *Sambucus nigra*. *E*, Epidermis; *PH*, phellogen; *L*, loosely disposed cells of the lenticel; *PL*, cambium of the lenticel; *PS*, phelloderm; *C*, cortical parenchyma containing chlorophyll. (From Sayre after Strasburger.)

There very early originate in the region beneath the stomata loosely arranged cells from cork cambium which swell up during rain and rupture, forming convex fissures in the cork layer, called lenticels.

The function of lenticels is similar to that of stomata, namely, to permit of aëration of delicate cells of the cortex beneath.

**Annual Thickening.**—In all woody exogenous stems such as trees and shrubs the persistent cambium gives rise to secondary xylem thickening every spring, summer and autumn. Soon a great cylinder of xylem arises which constitutes the wood of the trunk and branches. In the spring, growth is more active, and large ducts with little woody fiber are produced while in summer and autumn

growth is lessened and small ducts and much mechanical woody fiber are formed. Thus the open, loosely arranged product of the spring growth abuts on the densely arranged product of the last summer and autumn growth and the sharp contrast marks the periods of growth. To the spring, summer and autumn regions of growth of each year is given the term of "annual ring." By counting the number of these rings it is possible to estimate the age of the tree or branch.

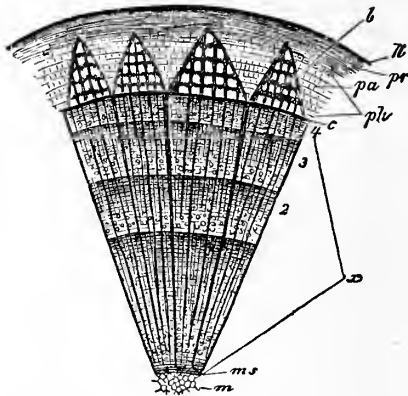


FIG. 47.—Part of a transverse section of a twig of the lime, four years old. *m*, Pith; *ms*, medullary sheath; *x*, secondary wood; *Ph*, phloem; 2, 3, 4, annual rings; *c*, cambium; *pa*, dilated outer ends of medullary rays; *b*, bast; *pr*, primary cortex; *k*, cork. (From Sayre after Vines.)

**Bark.**—Bark or bork is a term applied to all that portion of a woody exogenous plant axis outside of the cambium line.

In pharmacognic work, bark is divided into three zones, these from without inward being:

1. *Outer Bark or Cork.*
2. *Middle Bark or Cortical Parenchyme.*
3. *Inner Bark or Phloem.*

**Periderm.**—Periderm is a name applied to all the tissue produced externally by the cork cambium (*Phellogen*). This term appears often in pharmacognic and materia medica texts.

**Phelloderm.**—Phelloderm or secondary cortex is all that tissue produced by the cork cambium on its inner face.



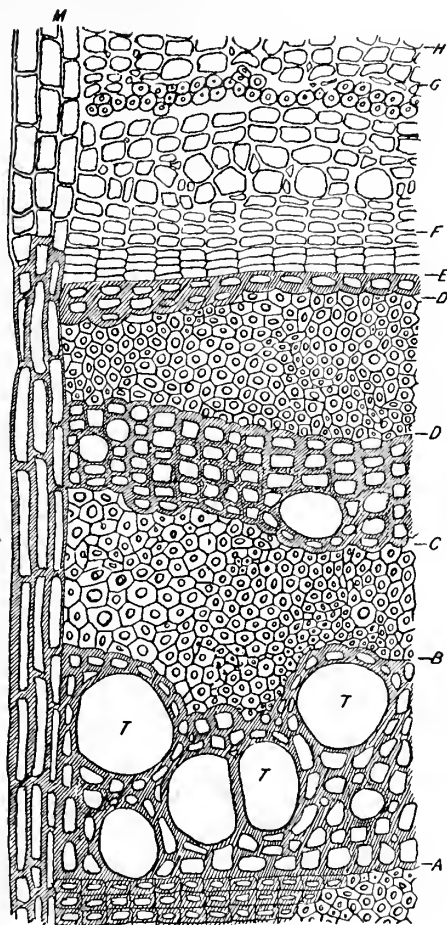


FIG. 48.—Part of a cross-section through branch of *Cytisus laburnum*. (The branch was cut from the tree at the end of October.) From A to E the last annual ring of wood; from A to B the spring growth with large tracheal tubes (T, T, T); between B and C and D and D are wood-fibers; between C and D and D and E, wood parenchyma; from E to F, cambium; F to G, phloem portion; G to H, cortical parenchyma; M, medullary ray. Below A the last wood-fibers and wood parenchyma formed the previous year. (From Sayre after Haberlandt.)

**Histology of a Typical Bark, Cascara Sagrada.**—*In transverse section* passing from outer to inner surface, the following structural characteristics are evident:

1. **Cork**, or outer bark, composed of several layers of rectangular cork cells. The most external layers are dead and appear black because they are filled with air. The inner layers of this region are living and contain brownish contents.

2. **Cork cambium** (phellogen), a layer of delicate cells with protoplasmic contents in the process of division.

3. **Cortex**, or middle bark, consisting of two regions, viz.: an outer zone of two or three rows of brownish collenchyme cells, and an inner broader *zone* of tangentially elongated cortical parenchyme cells. Imbedded within this zone will be noted numerous groups of stone cells.

4. **Phloem, or inner bark**, a very broad zone composed of irregular-shaped elongated phloem masses separated from each other by medullary rays which converge in the outer phloem region. Each phloem mass consists of numerous sieve tubes and phloem cells, some of which latter contain spheroidal starch grains while others contain monoclinic prisms or rosette aggregates of calcium oxalate. Embedded within the phloem masses in tier-like fashion will be noted groups of bast fibers, each group of which is surrounded by a row of crystal fibers, individual cells of which can only be made out in this kind of a section. Each of these contains a monoclinic prism of calcium oxalate. The medullary rays possess brownish contents which take a red color with an alkaline solution.

*In radial longitudinal section* a lengthwise view of the tissues will be seen. The medullary rays appear 15 to 25 cells in height and crossing at right angles to the other elements. The crystal fibers here will be seen to be composed of vertical rows of superimposed thin-walled cells each of which contains a monoclinic prism of calcium oxalate. The bast fibers appear elongated and taper ended and are associated with crystal fibers.

*In a tangential longitudinal section* which has been cut through the phloem, the exact range in width of the medullary rays may be ascertained. In this bark the medullary rays are spindle-shaped in tangential view and one to four cells in width.

**Wood.**—From a pharmacognic standpoint as well as that of the lumber trade, wood is all that portion of woody exogenous plant axes inside of the cambium line. In Dicotyl and Gymnosperm stems it therefore includes the xylem regions of the bundles, the

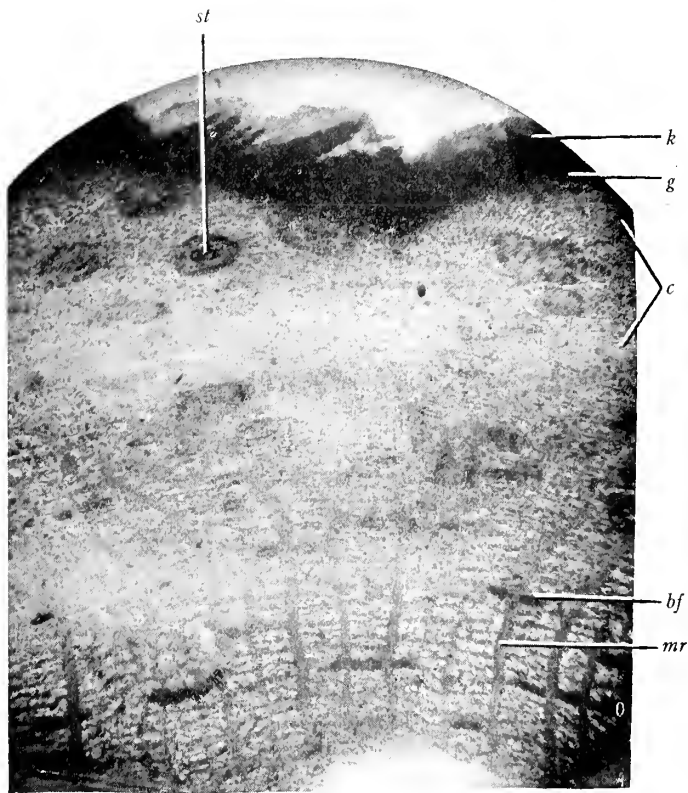


FIG. 49.—Photomicrograph of transverse section of Cascara Sagrada bark; *k*, cork; *g*, cork cambium; *c*, cortex; *st*, group of stone cells; *bf*, group of bast fibers; *mr*, medullary ray.

xylem portions of the medullary rays and the pith, while in the roots of secondary growth of these plants it comprises the xylem portions of the bundles and the xylem medullary rays.

As the cambium year after year adds new layers of wood to that

already present on its inner face, the conveying of sap and storing of starch, etc. is gradually relegated to the outer wood layers, since

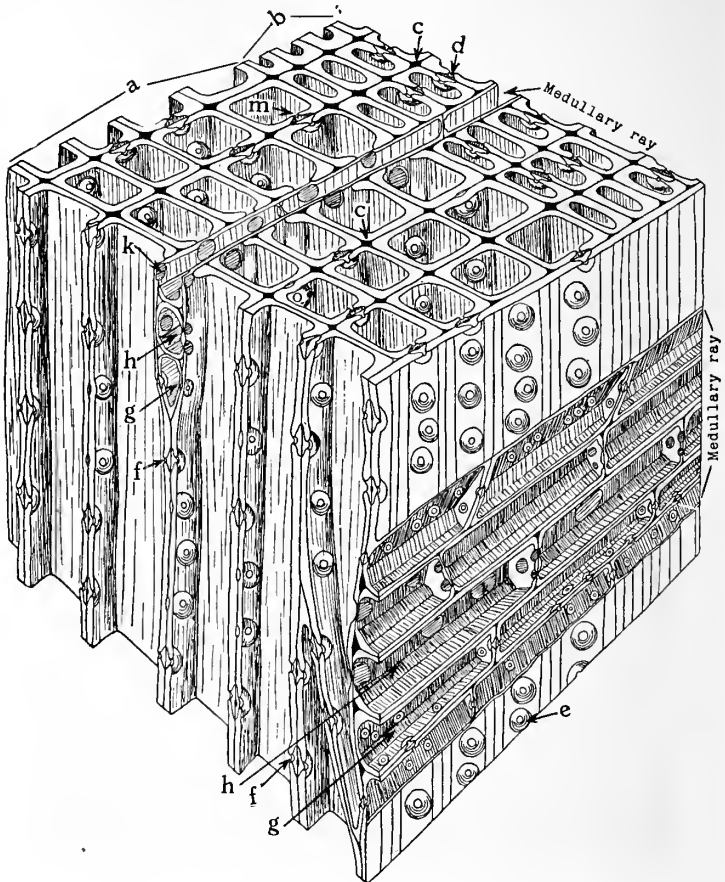


FIG. 50.—Diagrammatic representation of a block of pine wood highly magnified. *a*, Early growth; *b*, late growth; *c*, intercellular space; *d*, bordered pit in tangential wall of late growth; *m*, *f* and *e*, bordered pit in radial wall of early growth from different points of view; *h*, row of medullary cells for carrying food; *g*, row of medullary ray cells for carrying water; *k*, thin place in radial wall of ray cells that carry food. (From Stevens.)

the inner layers, step by step, lose their protoplasmic contents and power of conducting sap and become filled with extractive, resinous

and coloring matters. The outer whitish layers of wood which contain living cells, functioning in the vegetative processes of the plant, constitute the *alburnum* or *sap-wood*. The drug Quassia is a good example of this kind of wood. The inner dead colored layers constitute the *duramen* or *heart-wood*. Important examples of this kind of wood used in pharmacy are Lignum Guaiaci, Hæmatoxylum, and Santalum Album.

**Microscopic Characteristics of Angiospermous and Gymnospermous Woods.**—The wood of Angiosperms is characterized by the presence of tracheæ (vessels) with various markings on their walls, particularly by small pits in the walls of some of the tracheæ, together with wood fibers, wood parenchyma and medullary rays.

The wood of Gymnosperms is made up for the larger part of tracheids with-bordered pits which latter are characterized in radial longitudinal section by the presence of two rings, one within the other. A single row of these is seen on the tracheid wall. Medullary rays, frequently diagnostic for different species and woody parenchyme cells, are also found.

#### **Histology of Typical Herbaceous Monocotyl Stems (Endogenous).**

—Passing from exterior toward center the following structures are seen:

1. Epidermis whose cells are cutinized in their outer walls.
2. Hypodermis, generally collenchymatic.
3. Cortex.
4. Endodermis or innermost layer of cortex.
5. A large central zone of parenchyme matrix in which are found scattered fibro-vascular bundles of the closed collateral or rarely concentric type (amphivasal). In this latter type, which is typical of old monocotyl stems, the xylem grows completely around phloem so that phloem is found in the center and xylem without and surrounding it.

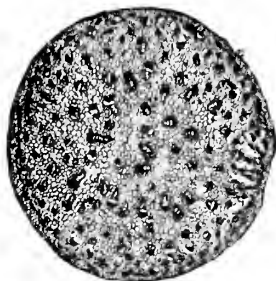


FIG. 51.—Photomicrograph of cross-section of very young cornstalk, where certain pterome strands have just gone over into vascular bundles. For comparison with Fig. 52. (Stevens.)

**Histology of a Typical Woody Monocotyl Stem.**—The stem of the Greenbrier, a woody monocotyl, will here be considered. In transverse section passing from periphery toward the center the following structural details will be noted:

1. *Epidermis*, of a single layer of epidermal cells whose outer walls are strongly cutinized. Cutin is a wax-like substance which forms a protective coat to the epidermis, preventing the evaporation of

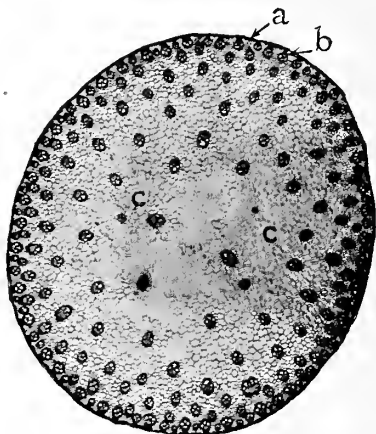


FIG. 52.—Cross-section of cornstalk stem; *a*, epidermis; *b*, cortex and *c*, ground tissue. (After Stevens.)

water, the ingress of destructive parasites, and injury from insects.

2. A *cortex*, composed of about ten or twelve layers of thick-walled parenchyme cells, the outer two or three layers of which are termed hypodermis.

3. An *endodermis*, wavy in character and composed of endodermal cells whose brownish walls are strongly suberized.

4. A sclerenchymatous *cylinder sheath* composed of somewhat separated masses of sclerenchymatous fibers and undeveloped fibrovascular bundles of the closed collateral type.

5. A *central matrix* of strongly thickened parenchyme cells in which are scattered, irregularly, numerous closed collateral bundles. Small starch grains will be found in the parenchyma cells. Examine a representative bundle, and note the two very large tracheæ and

several smaller ones in the xylem portion of the bundle which faces toward the center of the section. In the outer or phloem portion of the bundle will be seen an area of soft small-celled sieve tubes and phloem parenchyme. The entire bundle is enclosed by a several

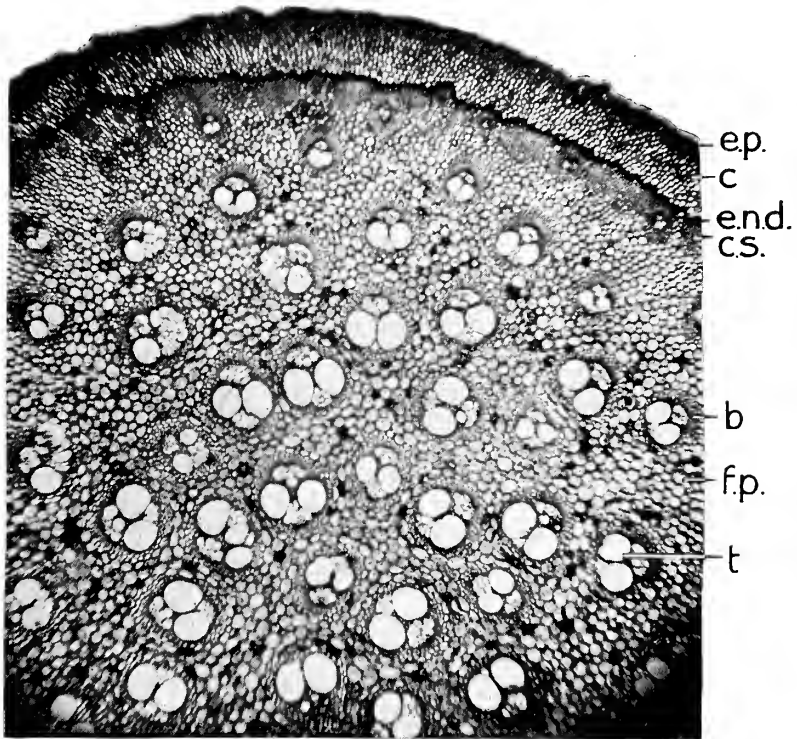


FIG. 53.—Photomicrograph of a representative portion of Greenbrier stem showing epidermis (*e.p.*), cortex (*c*), endodermis (*e.n.d.*), cylinder sheath (*c.s.*), sclerenchyme fibers of closed collateral bundle (*b*), fundamental parenchyma (*f.p.*), trachea (*t*).  $\times 22$ .

layered ring of sclerenchyme fibers, which on the inner face are called wood fibers, on the outer, bast fibers. The wood fibers constitute the supporting elements of the xylem, while the bast fibers are the supporting elements of the phloem.

## THE LEAF

The leaf is a usually flattened, rarely semi-centric, or centric-lateral expanse developed by the stem or by branches and in whose axil one or more branches arise.

Leaves seldom develop buds over their surface or along their margin and in connection therewith roots. The capacity for bud development is restricted to three families, viz.: Crassulaceæ, Begoniaceæ and Gesneraceæ.

*Leaf Functions.*—The most essential function of plants is the conversion of inorganic into organic matter; this takes place ordinarily in the green parts, containing chlorophyll, and in these when exposed to sunlight. Foliage is an adaptation for increasing the extent of green surface.

The functions of a leaf are photosynthesis, assimilation, respiration and transpiration.

**Photosynthesis** is the process possessed by all green leaves or other green parts of plants of building up sugar, starch or other complex organic substances by means of chlorophyll and sunlight. This process takes place in nature, only during sunlight.  $\text{CO}_2$  is taken in and O given off.

**Assimilation** is the process of converting food materials into protoplasm.

**Respiration** or breathing is the gaseous interchange whereby all living organisms take in oxygen and give off carbon dioxide.

**Transpiration** is the giving off of watery vapor.

**Types of Leaves Developed in Angiosperms.**—These may be tabulated as follows:

1. Cotyledons (the primitive or seed leaves).
2. Scale leaves.
3. Foliage leaves.
4. Bract leaves: (a) primary at base of inflorescence; (b) bracteolar leaves at base of individual flowers.
5. Sepals.
6. Petals.
7. Microsporophylls (stamens).
8. Megasporophylls (carpels).



**Cotyledons.**—Cotyledons are the first leaves to appear upon the ascending axis and are single in Monocotyledons, double in Dicotyledons. Occasionally, as in certain Maples, there may be three cotyledons shown. This is due to a splitting of one of the cotyledons. There exist no true cases of polycotyledony (development of many cotyledons) among Angiosperms as in Gymnosperms. In Monocotyledons the single cotyledon is a terminal structure and truly axial in relation to the hypocotyl and radicle. From a primitively Monocotyl-like ancestry Dicotyledons develop a second cotyledon on the Epicotyledonary node. Later, by a suppression of the second node the second cotyledon is brought to the level of the first.

**Scale Leaves.**—Scale leaves are reduced foliage leaves. They are found on certain rhizomes, above ground stems, such as Dodder, etc., on bulbs, and forming the protective scales of scaly buds.

**Foliage Leaves.**—These are the common green leaves so familiar to all.

**Bract leaves** are modified leaves appearing on inflorescence axes.

**Sepals, petals, microsporophylls** and **megasporophylls** are floral leaves and will be treated at length under the subject of the flower.

**Origin and Development of Leaves.**—Leaves arise around the growing apex region of a stem or branch as lateral outgrowths, each consisting at first of a mass of cells called the primordial leaf. Through continued cell-division and differentiation of these cells in time the mature leaf is developed. The primordial leaf is formed by a portion of the dermatogen of the growing stem apex, which becomes epidermis, a portion of the periblem, producing mesophyll which grows into this, and a part of the plerome, which becomes vascular tissue within the mesophyll.

In the sub-divisions of cells around the growing stem-apex, the primordial leaves (primordia) do not arise exactly at the same time. There is a tendency toward spiral arrangement.

**Phyllotaxy.**—Phyllotaxy is the study of leaf arrangement upon the stem or branch, and this may be either alternate, opposite, whorled, or verticillate, or fascicled. It is a general law in the arrangement of leaves and of all other plant appendages that they are spirally disposed, or on a line which winds around the axis like the thread of a screw. The spiral line is formed by the union of

two motions, the circular and the longitudinal, and its most common modification is the circle.

In the *alternate* arrangement there is but one leaf produced at each node.

*Opposite*, when a pair of leaves is developed at each node, on opposite sides of the stem. Example: Mints, Lilac.

*Decussate*, when the leaves are arranged in pairs successively along the stem, at right angles to each other.

*Whorled* or *Verticillate*, when three or more form a circle about the stem. Example: Canada Lily and Culver's root.

*Fascicled* or *Tufted*, when a cluster of leaves is borne from a single node, as in the Larch and Pine.

The spiral arrangement is said to be two-ranked when the third leaf is over the first, as in all Grasses; three-ranked, when the fourth is over the first. Example: Sedges. The five-ranked arrangement is the most common, and in this the sixth leaf is directly over the first, two turns being made around the stem to reach it. Example: Cherry, Apple, Peach, Oak and Willow, etc. As the distance between any two leaves is two-fifths of the circumference of the stem, the five-ranked arrangement is expressed by the fraction  $\frac{2}{5}$ . In the eight-ranked arrangement the ninth leaf stands over the first, and three turns are required to reach it, hence the fraction  $\frac{3}{8}$  expresses it. Of the series of fractions thus obtained, the numerator

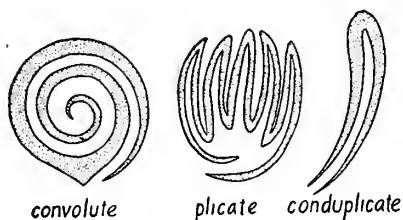


FIG. 54.—Three principal types of vernation. (Robbins.)

represents the number of turns to complete a cycle, or to reach the leaf which is directly over the first; the denominator, the number of perpendicular rows on the stem, or the number of leaves, counting along the spiral, from any one to the one directly above it.

**Vernation.**—*Prefoliation* or *Vernation* relates to the way in which leaves are disposed in the bud. A study of the individual leaf enables us to distinguish the following forms. When the apex is bent inward toward the base, as in the leaf of the Tulip Tree, it is said to be *inflexed* or *reclinate vernation*; if doubled on the midrib so that

the two sides are brought together as in the oak, it is *conduplicate*; when rolled inward from one margin to the other, as in the Wild Cherry, it is *convolute*; when rolled from apex to base, as in Ferns, it is *circinate*; when folded or plaited, like a fan as in Ricinus, Maples, Aralias, etc., it is *plicate*; if rolled inward from each margin, as the leaf of the common Violet, *involute*; when rolled outward from each margin as Rumex, *revolute*. The inner surface is always that which will form the upper surface when expanded.

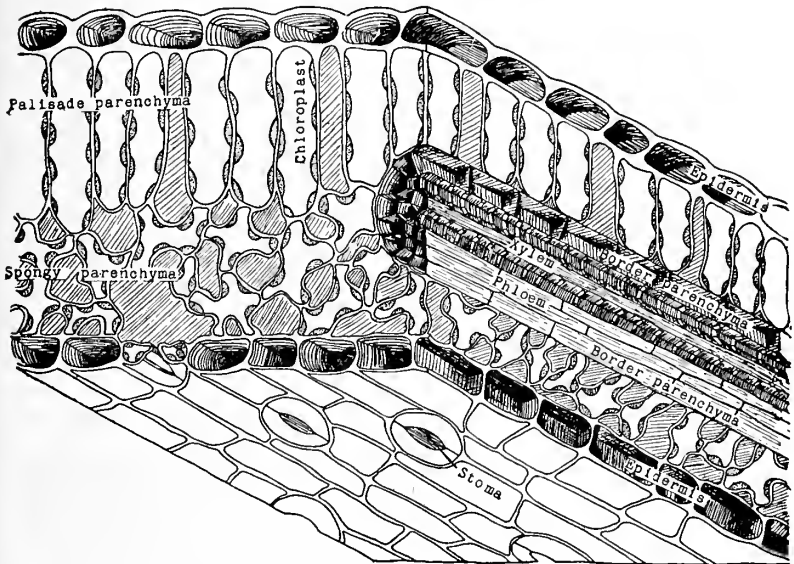


FIG. 55.—Stereogram of leaf structure. Part of a veinlet is shown on the right. Intercellular spaces are shaded. (From Stevens.)

**The Complete Leaf.**—The leaf when complete consists of three parts, *lamina*, *petiole*, and *stipules*. The lamina or blade is the expansion of the stem into a more or less delicate framework, made up of the branching vessels of the petiole.

The petiole is the leaf stalk. The stipules are leaf-like appendages appearing at the base of the petiole.

The leaf of the Tulip Poplar or *Liriodendron* affords a good example of a *Complete Leaf*.

Sometimes the lamina or blade is attached directly to the stem by its base and is then said to be *sessile*. If the petiole is present, *petiolate*.

When leaf stipules are absent, the leaf is said to be *exstipulate*, when present, *stipulate*.

The petiole is seldom cylindrical in form, but usually channelled on the upper side, flattened, or compressed. The stipules are always in pairs and closely resemble the leaf in structure.

The blade of the leaf consists of the framework, made up of branching vessels of the petiole, which are woody tubes pervading the soft tissue called mesophyll, or leaf parenchyme, and serve not only as supports but as veins to conduct nutritive fluids. Veins are absent in simple leaves such as many of the Mosses.

**Leaf Venation.**—*Furcate* or *Forked Venation* is characteristic of many Ferns.

*Parallel Venation* is typical of the *Monocotyledons*, as Palms, Lilies, Grasses, etc.

*Reticulate* or *Netted Veins* characterize the *Dicotyledons*, as the Poplar or Oak.

*Pinni-veined* or *Feathered-veined* leaves consist of a mid-vein with lateral veinlets extending from mid-vein to margin at frequent intervals and in a regular manner. Example: Calla.

*Palmately Veined* leaves consist of a number of veins of nearly the same size, radiating from petiole to margin. Example: Maple leaf.

Veins are said to be *anastomosing* when they subdivide and join each other, as the veins near the margin of *Eucalyptus* leaves.

**Leaf Insertion.**—The point of attachment of the leaf to the stem is called the insertion. A leaf is:

*Radical*, when inserted upon an underground stem.

*Cauline*, when upon an aerial stem.

*Ramal*, when attached directly to a branch.

When the base of a sessile leaf is extended completely around the stem it is *perfoliate*, the stem appearing to pass through the blade. Example: *Uvularia perfoliata* or Mealy Bellwort.

When a sessile leaf surrounds the stem more or less at the base, it is called *clasping* or *amplexicaul*. Example: Poppy (*Papaver somniferum*).

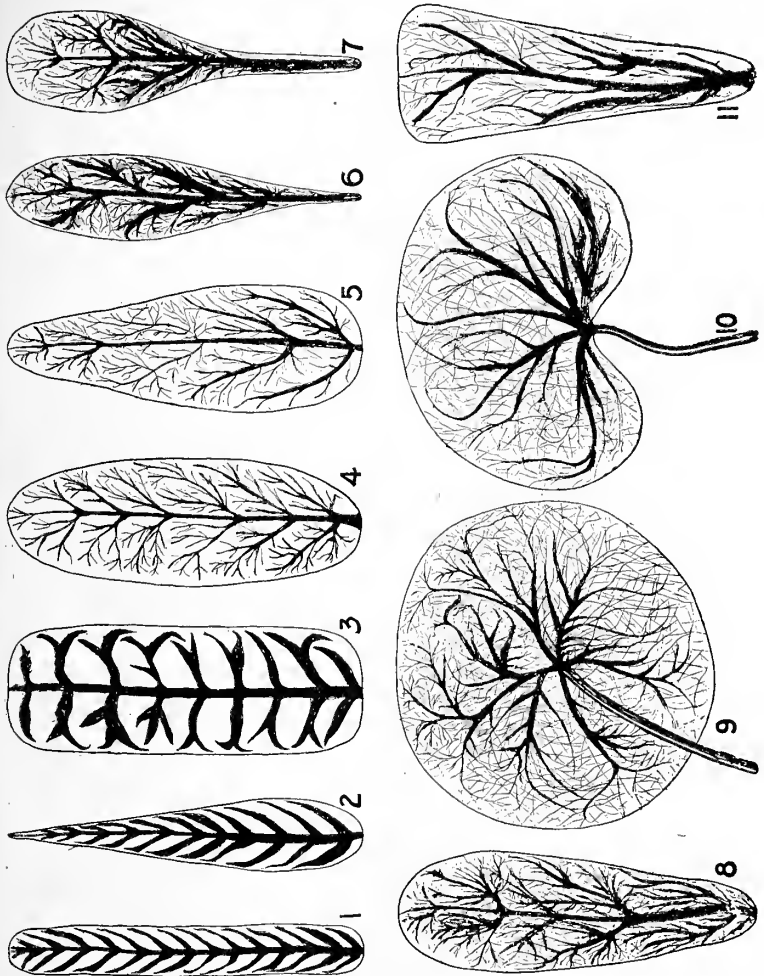


FIG. 56.—Leaf outlines: Linear (1); lanceolate (2); oblong (3); elliptical (4), ovate-lanceolate (5); oblanceolate (6); spatulate (7); obovate-lanceolate (8); orbicular (9); reniform (10); cuneate (11).

When the bases of two opposite leaves are so united as to form one piece, they are called *connate-perfoliate*, as *Eupatorium* or *Boneset*.

Leaves are called *equitant* when they are all radical and successively folded on each other, as the *Irish*.

**The Forms of Leaves.**—*Simple leaves* are those having a single blade, either sessile or petiolate.

*Compound leaves* are divided into two or more distinct subdivisions called leaflets, which may be either sessile or petiolate.

Simple leaves and the separate blades of compound leaves are described as to general outline, apex, base, marginal indentations, surface and texture.

(a) *General Outline* (form viewed as a whole without regard to indentations of margin). Dependent upon kind of venation.

When the lower veins are longer and larger than the others, the leaf is *Ovate*, or *Egg-shaped*. Example: *Parallel-veined* leaves are usually *linear*, long and narrow of nearly equal breadth throughout (*Linaria*), or *lanceolate*, like the linear with the exception that the broadest part is a little below the center. Example: *Long Buchu*.

*Elliptical*, somewhat longer than wide, with rounded ends and sides. Example: *Leaf of Pear*.

*Oblong*, when longer than broad, margins parallel. Example: *Matico*.

*Inequilateral*, margin longer on one side than the other, as the *Hamamelis*, *Elm* and *Linden*.

*Orbicular*, circular in shape. Example: *Nasturtium*.

*Peltate*, or shield-shaped, having the petiole inserted at the center of the lower surface of the lamina. Example: *Podophyllum*.

*Filiform*, or *thread-like*, very long and narrow, as *Asparagus* leaves.

*Ovate*, broadly elliptical. Example: *Digitalis*. *Obovate*, reversely ovate. Example: *Short Buchu*.

*Oblanceolate*, reversely lanceolate. Example: *Chimaphila*.

*Cuneate*, shaped like a wedge with the point backward.

*Spatulate*, like a spatula, with narrow base and broad rounded apex. Example: *Uva Ursi*.

*Ensiform*, when shaped like a sword. Example: *Calamus*.

*Acerose* or *acicular*, tipped with a needle-like point, as *Juniper*.

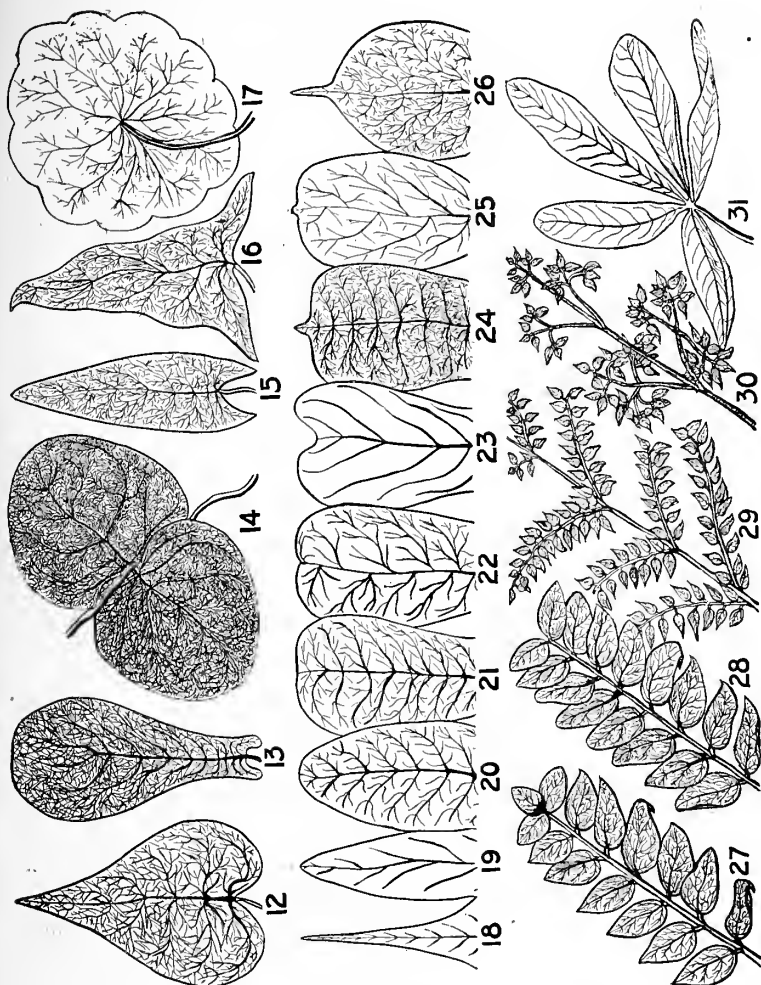


FIG. 57.—Leaf bases (12–17); leaf apices (18–26); compound leaves (27–31). Cordate (12); auriculate (13); connate-perfoliate (14); sagittate (15); hastate (16); peltate (17). Acuminate (18); acute (19); obtusate (20); truncate (21); retuse (22); emarginate (23); cuspidate (24); mucronate (25); aristate (26). Imparipinnate (27); paripinnate (28); bi-pinnate (29); decompound (30); palmately 5-foliolate (31).

*Deltoid*, when the shape of the Greek letter  $\Delta$ , as *Chenopodium*.

(b) **Apex of Leaf**.—*Acute*, when the margins form an acute angle at the tip of the leaf. Example: *Eriodictyon*.

*Acuminate*, when the point is longer and more tapering than the acute. Examples: *Pellitory*, *Coffee*.

*Obtuse*, blunt or round. Example: *Long Buchu*.

*Truncate*, abruptly obtuse, as if cut square off. (*Tulip Poplar*).

*Mucronate*, terminating in a short, soft point. Example: *Senna leaflets*.

*Cuspidate*, like the last, except that the point is long and rigid.

*Aristate*, with the apex terminating in a bristle.

*Emarginate*, notched. Example: *Pilocarpus*.

*Retuse*, with a broad, shallow sinus at the apex. Example: *Petal of Rosa gallica*.

*Obcordate*, inversely heart-shaped. Example: *Oxalis*.

(c) **Base of Leaf**.—*Cordate*, heart-shaped. Example: *Lime*.

*Reniform*, kidney-shaped. Examples: *Ground Ivy*, *Asarum*.

*Hastate*, or halbert-shaped, when the lobes point outward from the petiole. Example: *Aristolochia Serpentaria*.

*Auriculate*, having ear-like appendages at the base. Example: *Philodendron*.

*Sagittate*, arrow-shaped. Example: *Bindweed*.

(d) **Margin of Leaf**.—*Entire*, when the margin is an even line. Example: *Belladonna*.

*Serrate*, with sharp teeth which incline forward like the teeth of a hand-saw. Example: *Peppermint*.

*Dentate*, or toothed, with outwardly projecting teeth. *Chestnut*.

*Crenate*, or Scalloped, similar to the preceding forms, but with the teeth much rounded. Examples: *Digitalis*, *Salvia*.

*Repand*, or *Undulate*, margin—a wavy line. Example: *Hamamelis*.

*Sinuate*, when the margin is more distinctly sinuous than the last. (*Stamonium*.)

*Incised*, cut by sharp, irregular incisions. Example: *Hawthorn*.

*Runcinate*, the peculiar form of pinnately incised leaf observed in the *Dandelion* and some other *Compositæ* in which the teeth are recurved.

A *Lobed* leaf is one in which the indentations extend nearly to the



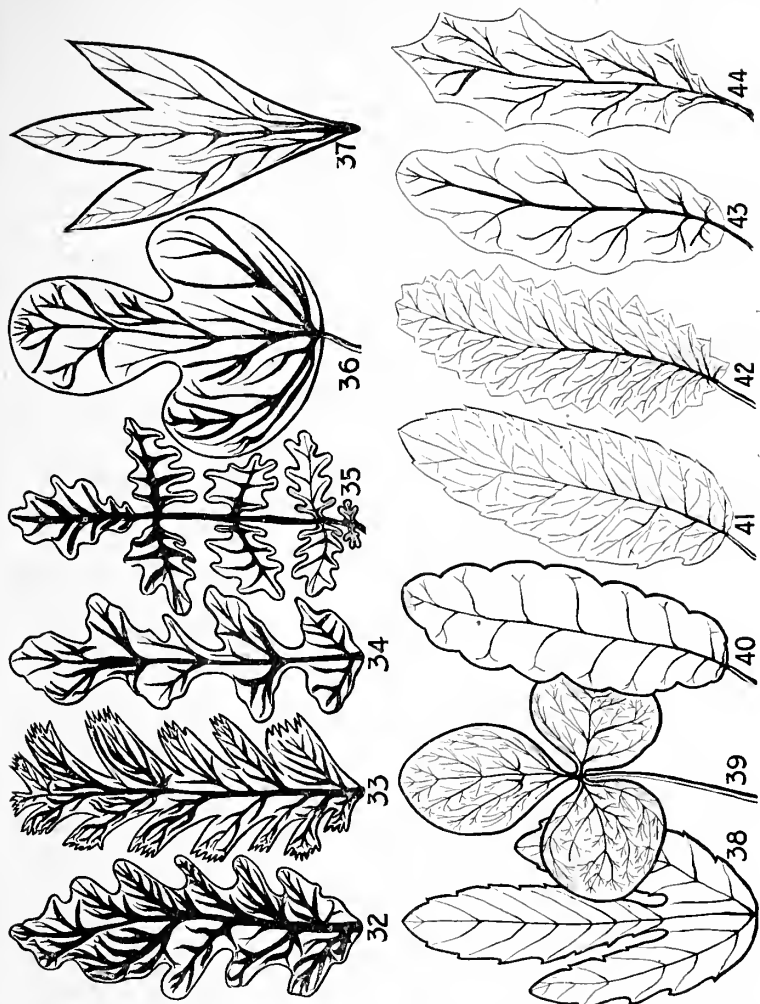


FIG. 58.—Leaf margins: Pinnately-lobed (32); pinnately-cleft (33); pinnately-parted (34); pinnately-divided (35); palmately tri-lobed (36); palmately tri-cleft (37); palmately 3-parted (38); palmately 3-divided (39); crenate (40); serrate (41); dentate (42); repand or undulate (43); sinuate-dentate (44).

mid-vein, or mid-rib, as it is usually called, the segments or sinuses, or both, being rounded. Example: Sassafras.

*Cleft* is the same as lobed, except that the sinuses are deeper, and commonly acute. Example: Dandelion.

A *Parted* leaf is one in which the incisions extend nearly to the mid-rib. Example: Geranium maculatum.

In the *Divided* leaf the incisions extend to the mid-rib, but the segments are not stalked. Example: Watercress.

If the venation is pinnate, the preceding forms may be described as pinnately incised, lobed, parted, or divided. If the venation is radiate, then the terms radiately or palmately lobed, incised, etc., are employed.

The transition from Simple to Compound Leaves is a very gradual one, so that in many instances it is difficult to determine whether a given form is to be regarded as simple or compound. The number and arrangement of the parts of a compound leaf correspond with the mode of venation, and the same descriptive terms are applied to outline, margin, etc., as in simple leaves.

Leaves are either pinnately or palmately compounded. The term pinnate is frequently given to the former while that of palmate is often assigned to the latter. They are said to be abruptly pinnate or paripinnate when the leaf is terminated by a pair of leaflets; odd pinnate or imparipinnate when it terminates with a single leaflet. When the leaflets are alternately large and small, the leaf is interruptedly pinnate, as the Potato leaf. When the terminal leaflet is the largest, and the remaining ones diminish in size toward the base the form is known as lyrate, illustrated in the leaf of the Turnip.

Palmately compound leaves have the leaflets attached to the apex of the petiole. When these are two in number the leaf is bifoliate, or binate; if three in number, trifoliate, or ternate; when four in number, quadrifoliate, etc. If each of the leaflets of a palmately compound leaf divides into three, the leaf is called biternate; if this form again divides, a triternate leaf results. Beyond this point the leaf is known as decompound. In the case of pinnately-compound leaves, when division progresses so as to separate what would be a leaflet into two or more, the leaf becomes bipinnate, as the compound leaves of Acacia Senegal or on the new wood of

Gleditschia; if these become again divided, as in many *Acacia* species, the leaf is termed tripinnate. Examples of decomposed leaves seen in *Cimicifuga* and Parsley.

**Leaf Texture.**—Leaves are described as:

*Membranous*, when thin and pliable, as Coca.

*Succulent*, when thick and fleshy, as Aloes, and Live Forever.

*Coriaceous*, when thick and leathery, as Eucalyptus, Uva Ursi and Magnolia.

**Leaf Color.**—*Petaloid*, when of some brilliant color different from the usual green, as the Coleus and Begonia, and other plants which are prized for the beauty of their foliage rather than their blossoms.

**Leaf Surface.**—Any plant surface is:

*Glabrous*, when perfectly smooth and free from hairs or protuberances. Example: Tulip.

*Glaucous*, when covered with bloom, as the Cabbage leaf.

*Pellucid-punctate*, when dotted with oil glands, as the leaves of the Orange family.

*Scabrous* leaves have a rough surface with minute, hard points.

*Pubescent*, covered with short, soft hairs. Example: Strawberry.

*Villose*, covered with long and shaggy hairs. Example: Forget-me-not.

*Sericious*, silky. Example: Silverleaf.

*Hispid*, when covered with short, stiff hairs. Example: Borage.

*Tomentose*, densely pubescent and felt-like, as the Mullein leaf.

*Spinose*, beset with spines, as in the Thistle.

*Rugose*, when wrinkled. Example: Sage.

*Verrucose*, covered with protuberances or warts.

**Duration of Leaves.**—Leaves vary as to their period of duration. They are: *Persistent*, or *evergreen*, if they remain green on the tree for a year or more.

*Deciduous*, if unfolding in spring and falling in autumn.

*Caducous*, or *fugacious*, if falling early in the season.

**Parts of Typical Leaf.**—The parts of a typical leaf are *petiole* or leaf stalk, *lamina* or blade, and *stipules*.

**Gross Structure and Histology of the Petiole.**—The *petiole* in Monocotyledons is usually a broadened, sheathing basal structure which connects the lamina to the stem. Into this a set of closed

collateral vascular bundles of the stem extend, these showing xylem uppermost and phloem beneath; but in the *Palmaceæ*, *Araceæ*, *Dioscoreaceæ* and *Musaceæ* the petiole in part or throughout may be much thickened, strengthened and developed as a semi-cylindric or cylindric structure frequently showing, as in *Palmaceæ*, generally, two sets of bundles. In all of these the petiole shows distinct scattered closed collateral bundles embedded in parenchyme and surrounded by epidermis. In the Monocotyl genus *Maranta* a special swelling is found at the apex of the petiole which is termed a *pulvinus*.

In Dicotyledons the petiole attains its most perfect development and here usually shows differentiation into a pulvinus or leaf cushion and stalk portion. The pulvinus is sensitive to environal stimuli and in some groups as *Oxalidaceæ* and *Leguminosæ* a gradual increase in sensitivity up to a perfect response can be traced. Moreover, in these, if we start with the simpler less sensitive pulvini and pass by stages to the most complex we note that a special substance known as the *aggregation body* develops in the pulvinar cortex cells and that this substance undergoes rapid molecular change on stimulation of the leaf. The stalk portion of the petiole in Dicotyledons is usually plano-convex or nearly to quite circular in outline; rarely in certain families does it simulate Monocotyledons in becoming abruptly or gradually thinned or flattened or widened out so as to sheath round the stem. The most striking example of this is seen in the *Umbelliferae* where the flattened sheathing leaf stalk is known as the *pericladium*. Such a structure is not peculiar to the *Umbelliferae* for in many *Ranunculaceæ*, etc., a similar sheathing development is observed. The stalk may bear the laminar tissue on its extremity. This is most commonly the rule, but when the plant is exposed to xerophytic conditions, as the Acacias of Australia, the stalk instead of being cylindric or sub-cylindric becomes flattened from side to side until there is produced a bifacial vertically placed petiole with a large green surface that wholly takes the place of the lamina.

The *petiolar structure* in primitive types of Dicotyls resembles that seen in Monocotyls except that the bundles are more condensed side by side. In these the petiole is somewhat dorsiventral, shows an external epidermis, a flattened cortex with a set of parallel vascular bundles each with xylem uppermost and phloem below.

From this we pass to another group in which the bundles form three-fourths of a circle and in which the upper bundles show incurving orientation, to still another in which as in *Nepenthes* all of the bundles form nearly a cylinder. Finally in *Ficus*, *Geranium*, *Podophyllum* and other plants showing completely formed cylindrical petioles, the bundles form a continuous ring enclosing pith and surrounded by cortex and epidermis as in Dicotyl stems.

**Stipules.**—Stipules are lateral leafy or membranous outgrowths from the base of the petiole at its junction with the stem. They may be divided into two groups, viz.: *lateral* and *axillary*. The *lateral group* includes four types, namely, free lateral, lateral adnate, lateral connate and lateral interpetiolar.

Free lateral stipules are seen in *Leguminosæ*, *Rosaceæ*, Beeches, etc. They are free on either side of the petiole and supplied by vascular tissue from the petiolar bundle mass. In appearance and duration they may be either green, foliaceous and persistent or membranous to leathery, scale-like and caducous. Caducous scaly stipules only function as bud scales through the winter and fall in spring as the buds expand.

Lateral adnate stipules are such as fuse with and are carried up with the petiole as wing-like appendages. This type is seen in the genus *Rosa*, in Clovers, etc.

Lateral connate stipules are such as join and run up with the petiole to form a structure which is called a *ligule*. This structure is common to the Graminaceæ or Grass family.

Lateral interpetiolar stipules are common to many species of the Rubiaceæ. In the genus *Cinchona* the leaves are opposite and originally had free lateral stipules which latter gradually fused with the stem, slid across it and adjacent stipules, then fused together to form a median structure on either side of the stem.

The *axillary group* represent stipules which stand in the axil of the leaf with the stem. Such may be free axillary structures, arising as distinct processes or connate, when the two stipules unite at their margins and sheath the stem, as in many species of the Polygonaceæ such as Buckwheat, Rhubarb, Yellow Dock, Knot Weeds, etc. The sheath formed is called an *ochrea*.

**Modified Stipules.**—In some plants such as the Locust and several

other trees and shrubs of the Legume family, the stipules become modified for defensive purposes as spines or prickles. In the Sarsaparilla-yielding plants and other species of the genus *Smilax* they undergo modification into tendrils which are useful in climbing.

*The Lamina.*—This as was previously indicated represents an expansion of the tissues of the petiole, but in sessile leaves is directly attached to the stem and so a direct stem outgrowth.

**Mode of Development of the Lamina of Leaves.**—The lamina of leaves develops in one of six ways.

1. Normal or Dorsoventral.
2. Convergent.
3. Centric.
4. Bifacial.
5. Reversed.
6. Ob-dorsi-ventral.

The first four will be considered.

A. **Dorsoventral** (the commonest).

(a) *Dorsoventral Umbrophytic.*—Flattened from above downward. Plants with such leafblades tend to grow in the shade.

(b) *Dorsoventral Mesophytic.*—Similar to the former, but plants usually grow directly in the open and exposed to sunlight and winds.

(c) *Dorsoventral Xerophytic.*—Similar to former, but plants not only grow exposed, but exposed to hot desert conditions or to cold vigorous conditions.

(d) *Dorsoventral Hydrophytic.*—All transitions between typical mesophytic forms to those of marshy places, to swamps and borders of streams and finally with leaves wholly emersed, the last a completely hydrophytic type.

**Gross Structure and Histology of Different Types of Dorsoventral Leaf Blades.**—1. **Umbrophytic.**—Characterized by leaves mostly undivided and having the largest and most continuous leaf expanse. Usually the deepest green leaves we have, to enable the leaves to absorb scattered and reduced rays that pass in through high trees and shrub overhead. Their texture is usually thin and soft. In microscopic structure they are covered with a cutinized epidermis which has all the stomata on the lower surface. The mesophyll is fairly spongy, the spongy parenchyme having decided intercellular

spaces. The lower epidermis is more or less hairy. Examples: Dog's Tooth Violet, Asters.

2. **Mesophytic.**—Leaves tend to subdivision, either to slight or moderate lobing, seldom to complete subdivision in pinnate or tripinnate fashion. Example: Dandelion. In microscopic struc-

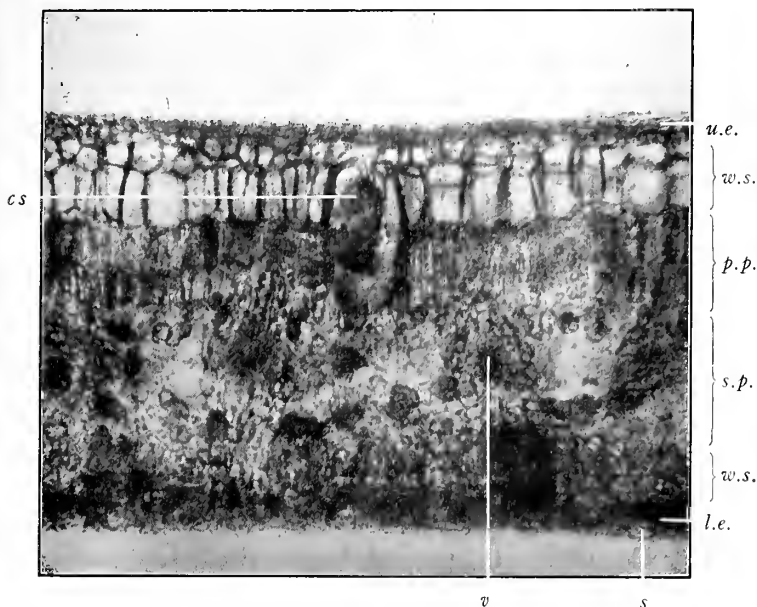


FIG. 59.—Photomicrograph of cross-section through a portion of the leaf of a xerophyte, *Ficus elastica*, showing upper epidermis (*u.e.*), water storage tissue (*w.s.*), cystolith suspended on stalk within a cystolith sac (*cys*), palisade parenchyma (*p.p.*), spongy parenchyma (*s.p.*), vein (*v*), lower epidermis (*l.e.*), and stoma (*s*). (Highly magnified.)

ture, they consist of an upper and lower epidermis, the upper epidermis being the thicker of the two. The stomata are wholly or are mainly on the lower epidermis. Hairs are seldom seen. The palisade mesophyll is toward the upper surface, the spongy mesophyll toward the lower. The intercellular air spaces in the spongy parenchyma are small.

3. **Xerophytic.**—Leaves characterized by a thick upper and lower cuticle and by having their numerous, small stomata restricted to

the lower surface or present more or less equally on both surfaces, where they are sunken in depressions. They may be either firm, leathery, tough, fibrous, or may become swollen up in their mesophyll chiefly in their spongy parenchyme cells and store considerable mucilage. Examples: *Yucca*, *Ficus*, *Aloe*, *Agave*. Succulent forms like *Aloe* generally possess a thin but tenacious cuticle.

4. **Hydrophytic.**—All gradations are seen. In pond plants, such as the Water Lily, the leaves have long split petioles which bring the blade up to the surface of the water. The stomata are entirely

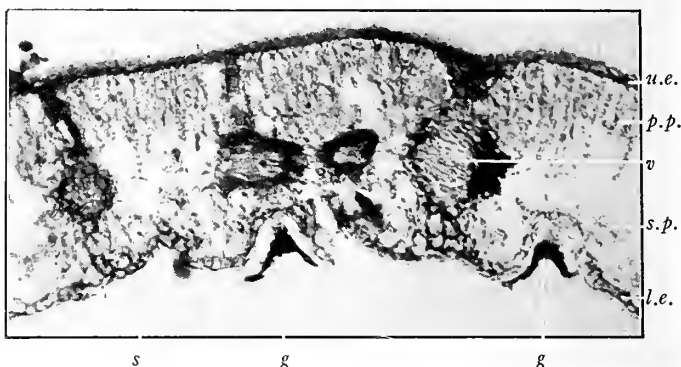


FIG. 60.—Photomicrograph of dorsoventral leaf of *Myrica* showing upper epidermis (*u.e.*), palisade parenchyma (*p.p.*), vein (*v*), spongy parenchyma (*s.p.*), lower epidermis (*l.e.*), glandular-hairs (*g*) and stoma (*s*). (Highly magnified.)

on the upper surface. In *Ranunculus*, the lower leaves are cut up into filiform segments. These are devoid of stomata. Their mesophyll is soft, open, and spongy. The epidermis is quite thin. The upper leaves are floating, trilobed, and have stomata only on their upper surface. In *Utricularia*, some of the filiform submerged leaves are modified into bladders which trap insect larvæ and smaller Crustaceæ.

B. **Convergent.**—In *Phormium tenax*, the base of the blade is sheathing, it then converges and opens out above. In the various species of *Iris* the petiole is sheathing, the upper part being fused (mostly seen in monocotyls).

C. **Centric.**—*Succulent.*—Nearly always associated with Xerophytes.



*Xerophytic*.—Centric laminae are produced gradually by an encroachment of the under on the upper surface, and the swelling of the whole. In a completely centric leaf of the succulent kind, like that of *Sedum*, the difference between the upper and lower surface is lost. Stomata are found scattered over the entire epidermis. The bundles

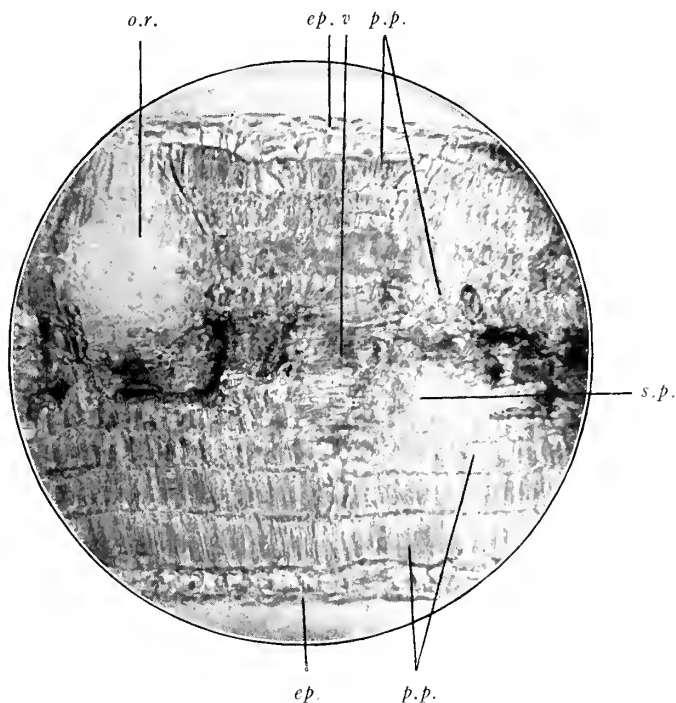


FIG. 61.—Photomicrograph of a transverse section of a bifacial leaf of *Eucalyptus globulus* showing epidermis (ep.), palisade parenchyma (p.p.), toward both surfaces, spongy parenchyma (s.p.), vein (v), and oil reservoir (o.r.) lined with secretory epithelium. (Highly magnified.)

are arranged in a circle, the mid-rib being in the center. A great deal of mucilage is found stored in the central cells. In a typical Xerophytic Centric leaf, like that of the Pine or *Sansevieria cylindrica*, the epidermis shows a thick cuticle; the stomata are sunken in cavities of the epidermis; the epidermis and leaf tissue are strengthened by scleroid bands in the centric mesophyll.

D. **Bifacial.**—Leaves with laminæ which stand edge on in relation to the sun's rays. The best illustrations are seen among dicotyledons, such as *Eucalyptus*, *Callistemon*, and other genera of *Myrtaceæ*. Both surfaces are similar, having stomata about equal in number. The mesophyll is differentiated into a central spongy parenchyme containing bundles, and a zone of palisade cells on either side facing the surfaces.

**Structure and Development of Stomata.**—Stomata are slit-like openings in the epidermis of leaves or young green stems surrounded by a pair of cells called guard cells whose sides opposite one another are concave. They form a communication between the intercellular-air-space (respiratory cavity) beneath them and the exterior. The slit-like opening taken with the guard cells, constitutes what is known as the stomatal apparatus.

The epidermal cells which abut on the stomatal apparatus are called *neighboring cells* or *subsidiary cells*. These in many cases, as in species of *Helleborus*, *Sambucus*, *Hyacinthus*, *Pæonia*, Ferns, etc., are very similar to the other epidermal cells but in a large number of plants they differ in size, arrangement and shape from the other cells of the epidermis which do not abut upon the stomatal apparatus. In *Senna* they are two in number one larger than the other and arranged parallel to the guard cells of the stoma; in *Coca* a similar arrangement occurs but the cells are more even in size, nevertheless they lack the characteristic papillæ found on the other epidermal cells; in *Pilocarpus* they are usually four in number but quite narrow and more or less crescent-shaped; in *Uva Ursi* their number is usually seven to eight and their arrangement radial around the stomatal apparatus.

On all dorsoventral leaves, the stomata arise more abundantly on the lower epidermis, less abundantly on the upper. Exceptions to this rule are due to the peculiar readaptation of the leaf to its surroundings. Thus, in the reversed types of leaves (twisted in a half circle) the stomata, formerly on the lower surface, have migrated to the upper surface which now has become the physiological lower surface.

In Umbrophytic (shade) plants the stomata are either wholly on the lower surface or partly so with a number on the upper surface. Where the plants are Mesophytic and exposed to dense sunlight and

leaves remain dorsiventral, the stomata are on the lower surface; these stomata are large, if the surroundings are damp. If such plants live in dry soil and dry air, the stomata are of small size and numerous; if they dwell in dry soil in hot surroundings and dense light they are very small and frequently sunk. If the plants are Xerophytic and the leaves dorsoventral, the stomata are quite abundant, small, with narrow slit, and depressed below the level of the epidermis.

There are five types of stomatal development, viz.:

**First Type.**—Each primitive epidermal cell (or the majority, or only certain ones of the epidermis) at the close of the dermatogen stage, gradually lengthens and then cuts off a smaller from a larger cell. The smaller one is equilateral, has a very large nucleus, and is termed the *Stoma Mother-cell*; the larger, quadrangular, and called the *Epidermal Daughter-cell*. The latter, upon maturing, becomes a normal epidermal cell. A partition is laid down lengthwise through the *Stoma Mother-cell* dividing it into two stomatal daughter-cells. The wall laid down lengthwise splits and thus forms the orifice of the stoma; the cells on either side of the orifice are called *Guard Cells*. These, while at first flat and inoperative, soon become bulged and crescent-shaped. This mode of development is seen in *Squill*, *Hyacinth*, *Daffodil*, *Sambucus*, *Silene*, etc.

**Second Type.**—After the cutting off of the stomal mother-cell there are cut off on either side portions of neighboring epidermal cells which form subsidiary cells to the stoma. This condition is seen in *Graminaceæ*, *Cyperaceæ*, *Juncaceæ*, in various species of *Aloe*, *Musa* and *Proteaceæ*.

**Third Type.**—Instead of two parallel subsidiary cells, four are cut off, as in *Heliconia*, in species of *Tradescantia*, *Araucaria*, or four to five, as in *Ficus elastica*, or four to five or more, as in the *Coniferæ* and *Cycads*.

**Fourth Type.**—Instead of only four subsidiary cells, each of these again subdivides by parallel walls, more rarely by radial walls, into eight radiating subsidiary cells, as in *Maranta bicolor*, *Pothos argyræa*, some of *Proteaceæ*, etc.

**Fifth Type.**—The “stomal mother-cell” divides once or several times before becoming the true mother-cell of the stoma. As a result of the divisions there are also formed one or more subsidiary

cells. This mode of development is seen in the *Labiata*, *Papilionaceæ*, *Crucifera*, *Solanaceæ*, *Crassulaceæ*, *Cactaceæ*, and *Begoniaceæ*, also in a number of ferns.

**Histologic Differences between Leaves of Dicotyledons and Monocotyledons.**—The following may be cited as broad comparative histologic differences between Dicotyl and Monocotyl leaves:

*Dicotyl Leaves*

1. Epidermal cells usually iso-diametric or sinuous.
2. The stomata are on the whole more numerous but smaller.
3. Non-glandular and glandular hairs frequent on upper but more frequent on lower surface, or both.
4. Leaf glands which excrete varied products are rather abundant.
5. Water stomata over the upper surface, more rarely over the lower surface, are frequent, especially along margins of leaves.
6. Palisade and spongy parenchyma in dicotyledons are more distinct and palisade parenchyma is denser.
7. The vascular bundles, in their intrinsic elements, are more indurated but the accessory fibrous sheath is feebly developed.
8. A greater variety of accessory products of assimilation are developed.

*Monocotyl Leaves*

1. Epidermal cells usually elongate and equilateral.
2. Stomata larger.
3. Hairs rare in Monocotyls.
4. Leaf glands rare and only seen as a rule on the sepals.
5. Water stomata absent or very rare. Present in some *Araceæ*.
6. Palisade and spongy parenchyma is less distinct and dense.
7. The vascular bundles, in their intrinsic elements, are less indurated. The fibrous sheath is strongly developed.
8. A comparatively small variety of accessory products of assimilation are developed.

## INFLORESCENCE

**Inflorescence or Anthotaxy.**—A typical flower consists of four whorls of leaves modified for the purpose of reproduction, and compactly placed on a stem. The terms Inflorescence and Anthotaxy are applied to the arrangement of the flowers and their position on the stem, both of which are governed by the same law which determines the arrangement of leaves. For this reason flower buds are always either terminal or axillary. In either case the bud may develop a

solitary flower or a compound inflorescence consisting of several flowers.

*Determinate, cymose, descending, or centrifugal* inflorescence is that form in which the flower bud is terminal, and thus determines or completes the growth of the stem. Example: *Ricinus communis*.

*Indeterminate, ascending, or centripetal* inflorescence is that form in which the flower buds are axillary, while the terminal bud continues to develop and increase the growth of the stem indefinitely. Example: the Geranium.

*Mixed inflorescence* is a combination of the other two forms. Example: Horse Chestnut.

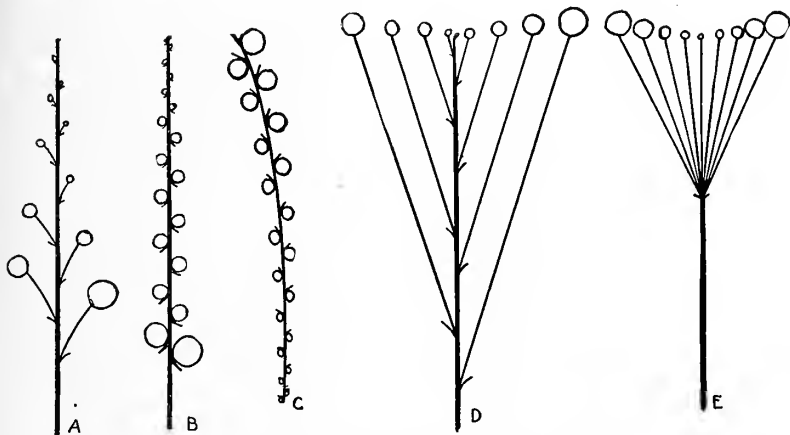


FIG. 62.—Types of indeterminate inflorescence. A, A raceme; B, a spike; C, a catkin; D, a corymb; E, an umbel. The flowers are represented by circles; the age of the flower is indicated by the size. (From Hamaker.)

The flower stalk is known as the *peduncle*, and its prolongation the *rachis*, or axis of the inflorescence.

The flower stalk of a single flower of an inflorescence is called a *pedicel*. When borne without such support the flower is *sessile*.

A peduncle rising from the ground is called a *scape*, previously mentioned under the subject of stems.

The modified leaves found on peduncles are termed *bracts*. These vary much the same as leaf forms, are described in a similar manner,

and may be either green or colored. When collected in a whorl at the base of the peduncle they form an *involucre*, the parts of which are sometimes imbricated or overlapping, like shingles. This is generally green, but sometimes petaloid, as in the Dogwood. The

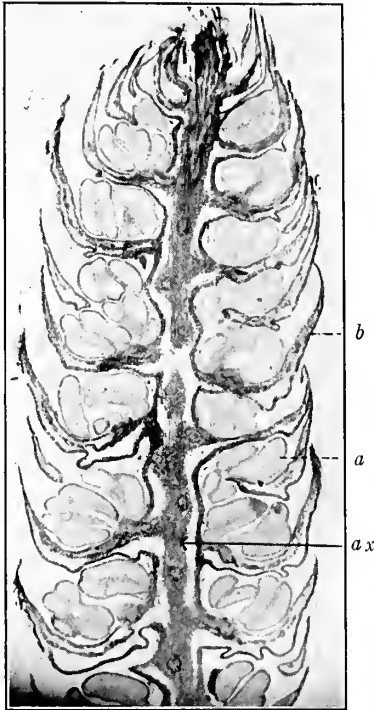


FIG. 63.—Photomicrograph of longitudinal section through a staminate catkin of *Comptonia asplenifolia*  $\times 10$ , showing catkin axis (*ax*), anther-lobe (*a*), and bract (*b*).

modified leaves found on pedicels are called *bracteolar leaves*.

The *Spathe* is a large bract enveloping the inflorescence and often colored, as in the Calla, or membranous, as in the Daffodil.

**Indeterminate Inflorescences.**—In the indeterminate or axillary anthotaxy, either flowers are produced from base to apex, those blossoming first which are lowest down on the rachis or from margin to center. The principal forms of this type are:

*Solitary Indeterminate.*—The simplest form of inflorescence in which a single flower springs from the axil of a leaf. A number of these are generally developed on the same stem. Example: Periwinkle.

*Raceme*, or simple flower-cluster in which the flowers on pedicels of nearly equal length are arranged along an axis. Examples: Convallaria, Cimicifuga, and Currant.

*Corymb*, a short, broad cluster, differing from the raceme mainly in its shorter axis and longer lower pedicels, which give the cluster a flat appearance by bringing the individual florets to nearly the same level. Example: Cherry.

*Umbel*, which resembles the raceme, but has a very short axis, and

the nearly equal pedicels radiate from it like the rays of an umbrella. Many examples of this mode of inflorescence are seen in the family *Umbelliferae*, as indicated by the name, including Anise, Fennel and other drug-yielding official plants.

A *Spike* is a cluster of flowers, sessile or nearly so, borne on an elongated axis. The Mullein and common Plantain afford good illustrations.

The *Catkin* or *Ament* resembles the Spike, but differs in that it has scaly instead of herbaceous bracts, as the staminate flowers of the Oak, Hazel, Willow, *Comptonia*, etc.

The *Head* or *Capitulum* is like a spike, except that it has the rachis shortened, so as to form a compact cluster of sessile flowers, as in the Dandelion, Marigold, Clover, and Burdock.

The *Strobile* is a compact flower cluster with large scales concealing the flowers, as the inflorescence of the Hop.

The *Spadix* is a thick, fleshy rachis with flowers closely sessile or embedded on it, usually with a spathe or sheathing bract. Example: *Calla*, *Acorus Calamus*, *Arum triphyllum*.

The compound raceme, particularly if irregularly compounded, is called a *panicle*.

**Determinate Inflorescences.**—*Determinate Anthotaxy* is one in which the first flower that opens is the terminal one on the axis, the other appearing in succession from apex to base or from center to margin. The principal varieties are:

The *Solitary Determinate*, in which there is a single flower borne on the scape, as in the *Anemone*, or Windflower, and *Hydrastis*.

The *Cyme*, a flower cluster resembling a corymb, except that the buds develop from center to circumference. Example: Elder. If the cyme be rounded, as in the Snowball, it is a globose cyme.

A *Scorpid Cyme* imitates a raceme, having the flowers pedicelled and arranged along a lengthened axis.

A *Glomerule* is a cymose inflorescence of any sort which is condensed into a head, as the so-called head of *Cornus florida*.

A *Verticillaster* is a compact, cymose flower cluster which resembles a whorl, but really consists of two glomerules situated in the axils of opposite leaves. Clusters of this kind are seen in Catnip, Horehound, Peppermint and other plants of the *Labiatae*.

The raceme, corymb, umbel, etc., are frequently compounded. The compound raceme, or raceme with branched pedicels, is called a panicle. Examples: *Yucca* and paniculate inflorescence of the oat.

A *Thyrsum* is a compact panicle, of a pyramidal or oblong shape. Examples: Lilac, Grape and *Rhus glabra*.

A *Mixed Anthotaxy* is one in which the determinate and indeterminate plans are combined, and illustrations of this are of frequent occurrence.

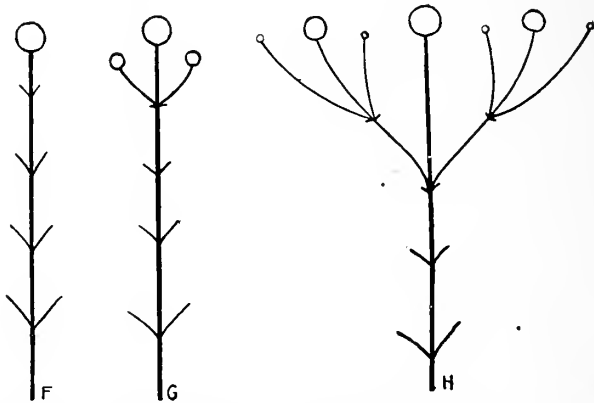


FIG. 64.—Cymose inflorescences. *F*, A terminal flower; *G*, a simple cyme; *H*, a compound cyme. (From Hamaker.)

The order of flower development is termed ascending when, as in the raceme, the blossoms open first at the lower point on the axis and continue to the apex. Examples: White Lily, and many other plants of the same family. In the cyme the development is centrifugal, the central florets opening first, while in the corymb it is centripetal, or from margin to center.

### PREFLORATION

**Prefloration.**—By prefloration is meant the arrangement of the floral envelopes in the bud. It is to the flower bud what vernation is to the leaf bud, the same descriptive terms being largely employed, as convolute, involute, revolute, plicate, imbricate, etc.

In addition to those already defined, the following are important.



*Valvate Prefloration*, in which the margins meet but do not overlap. Of this variety the induplicate has its two margins rolled inward as in Clematis. In the reduplicate they are turned outward, as the sepals of Althaea.

*Vexillary*, the variety shown in the corolla of the Pea, where the two lower petals are overlapped by two lateral ones, and the four in turn overlapped by the larger upper ones.

*Contorted*, where one margin is invariably exterior and the other interior, giving the bud a twisted appearance, as in the Oleander and Phlox.

### THE FLOWER

The flower is a shoot which has undergone a series of changes so as to serve as a means for the propagation of the individual.

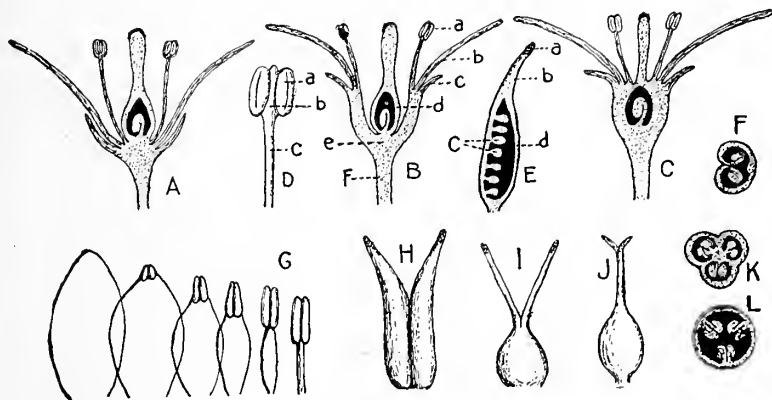


FIG. 65.—Diagrams of floral structures. A, Shows the relations of the floral parts in a hypogynous flower; B, the same in a perigynous flower; C, the same in an epigynous flower; D, a stamen; E, a simple pistil in longitudinal section; F, the same in cross-section; G, transitional forms between true petals (left) and true stamens (right); H, slight union of two carpels to form a compound pistil; I and J, union of carpels more complete; K and L, cross-sections of compound pistils, of three carpels. In B: a, stamen; b, petal; c, sepal; d, pistil; e, receptacle; f, pedicel. In D: a, anther cell; b, connective; c, filament. In E: a, stigma; b, style; c, ovules; d, ovary. (From Hamaker.)

A *Typical* or *Complete Flower* possesses four whorls of floral leaves arranged upon a more or less shortened stem axis called a *receptacle*, *torus* or *thalamus*. These whorls passing from periphery toward the

center are: *calyx*, composed of parts called sepals; *corolla*, composed of parts termed petals; *andræcium*, composed of parts called stamens or microsporophylls; and *gynæcium*, composed of one or more parts termed carpels or megasporophylls.

The stamens and carpels constitute the *essential* organs, and a flower is said to be *Perfect* when these are present and functional.

A *Hermaphrodite* flower is one which possesses both stamens and carpels which may or may not be functionally active. In some cases the stamens may alone be functional while in others the carpels only may function.

A *Regular Flower* possesses parts of each whorl of the same shape and size, as the flower of *Veratrum*.

It is *Symmetrical* when the parts of each whorl are of the same number, or multiples of the same number.

An *Imperfect Flower* shows one set of *essential* organs wanting.

When either petals or sepals, or both, are present in more than the usual number, the flower is said to be "*double*," as the cultivated Rose and Carnation. The doubling of flowers is brought about through cultivation and is due either to the transformation of stamens (as in cases cited), and occasionally of carpels into petals, to a division of the petals, or to the formation of a new series of petals.

If the pistils are present and stamens wanting, the flower is called *pistillate*, or female; if it possesses stamens but no pistil, it is described as *staminate*, or male; if both are absent, *neutral*, as marginal flowers of *Viburnum*. Some plants, as the Begonias and Castor oil bear both staminate and pistillate flowers, and are called *Monæcious*. When the staminate and pistillate flowers are borne on different plants of the same species, they are termed *Diæcious*, as the Sassafras and Willow. When staminate, pistillate and hermaphrodite flowers are all borne on one plant, as on the Maple trees, they are *polygamous*.

**Connation and Adnation.**—In the development of the flowers of primitive species of flowering plants, the parts of each whorl are disjoined or separate from each other. In many higher types, however, the parts of the same whorl frequently become partly or completely united laterally. This condition is termed *connation*, *coalescence*, *cohesion* or *syngensis*. Illustrations of this may be seen in *Belladonna*, *Stramonium* and *Uva Ursi* flowers, where the petals have

joined laterally to form gamopetalous corollas. When the one or more parts of different whorls are united, as of stamens with petals (*Rhamnus*) or stamens with carpels (*Apocynum*) the union is called *adnation* or *adhesion*.

**The Receptacle.**—The *Receptacle*, *Torus* or *Thalamus* is a more or less shortened axis (branch) which bears the floral leaves. It is usually flat or convex, but may be conical and fleshy as in the Strawberry, concave as in the Rose and Fig or show a disc-like modification as in the Orange. The internodes of the receptacle in many species lengthen and separate various whorls. When the lengthening of the internode occurs between calyx and corolla as in *Lychnis* the structure resulting is called an *anthophore*; if between corolla and andrœcium as in *Passiflora*, a *gonophore*; if between andrœcium and gynœcium as in *Geum*, a *gynophore*. If the flowers of the *Umbelliferae* the receptacle elongates between the carpels producing the structure called a *carpophore*.

**The Perigone.**—The perigone or perianth is the floral envelope consisting of calyx and corolla (when present).

When both whorls, *i.e.*, calyx and corolla, are present the flower is said to be *dichlamydeous*; if only calyx is present, *monochlamydeous*.

**The Calyx.**—The Calyx is the outer whorl of modified leaves. Its parts are called Sepals, and may be distinct (Chorisepalous, from a Greek word meaning disjoined) or more or less united (Gamosepalous). They are usually green—foliaceous or leaf-like—but may be brilliantly colored, hence the term petaloid (like the petals) is applied. Examples: Tulip, Larkspur, Columbine and Aconite.

In a *gamosepalous calyx*, when the union of sepals is incomplete, the united portion is called the *tube*, the free portion, the *limb*, the orifice of the tube, the *throat*.

In form the calyx may be regular or irregular; regular, if its parts are evenly developed, and irregular if its parts differ in size and shape. The more common forms are tubular, resembling a tube; rotate, or wheel-shape; campanulate, or bell-shaped; urceolate, or urn-shape; hypocrateriform, or salver-shape; bilabiate, or two-lipped; corresponding to the different forms of corolla, under which examples illustrating each will be given.

The calyx usually remains after the corolla and stamens have

fallen, sometimes even until the fruit matures—in either case it is said to be persistent. If it falls with the corolla and stamens, it is deciduous, and if when the flower opens, caducous, as in the Poppy and May-apple. It often more or less envelops the ovary or base of the pistil, and it is important, in plant analysis, to note the presence or absence of such a condition, which is indicated in a description by the terms inferior, or non-adherent (hypogynous), when free from the ovary and inserted upon the receptacle beneath it (the most simple and primitive position); half-superior, or half-adherent (perigynous), when it partially envelops the ovary, as in the Cherry; superior or adherent (epigynous), when it completely envelops it, as in the Colocynth, etc.

**Sepaline Spurs.**—Occasionally some or all of the sepals may become pouched and at length spurred as nectar receptacles or as receptacles for other parts that are nectariferous. Thus, in *Cruciferae* we occasionally see a slight pouching of the two lateral sepals. These act as nectar pouches for the nectar secreted by the knobs or girdles surrounding the short lateral stamens. These become deep pouches in *Lunaria* while in others the pouches become elongated spurs. Again, in *Delphinium*, the posterior sepal forms an elongated spur into which pass the two spurred nectariferous petals. In *Aconitum* the same sepal, instead of being spurred, forms an enlarged hood-like body (galea) arching over the flower like a helmet; into this pass the two hammer-shaped nectariferous petals.

**Sepaline Stipules.**—These structures are well developed and easily traceable in the more primitive herbaceous members of the Rose family. Thus in *Potentilla*, *Fragaria*, *Geum*, etc., in addition to the normal calyx of five sepals, there is a supplementary *epicalyx* also of five parts. The five lobes of the epicalyx may be as large or larger than the sepals or smaller up to the disappearing point. Upon examining a few flowers of *Potentilla* or *Fragaria*, it will be observed that not infrequently one, sometimes two lobes of the epicalyx are bifid, or deeply cleft, or separated completely into two parts. The explanation is that the five sepals after evolving in the flower bud form at their bases two lateral swellings or *sepaline stipules*, which, as they grow, fuse in adjacent pairs, one stipule of one sepal joining with the adjacent stipule of another sepal to form five lobes.

**Sepaline Position.**—As already noted the most simple and primitive position for the sepals in relation to the floral parts is *hypogynous*, in which the sepals are inserted directly into the enlarged floral axis (receptacle) below the petals, stamens and carpels. But in the more primitive herbaceous *Rosaceæ*, *Leguminosæ*, etc., the floral axis forms a saucer-like transverse expansion which pushes out the sepals, petals and stamens on its edge. Thus originates the *perigynous* insertion of the sepals. In not a few higher *Rosaceæ*, *Saxifragaceæ*, *Crassulaceæ*, etc., the saucer-like floral axis becomes deepened and contracted into a cup-shaped structure (Cherry, Peach, Almond, Plum, etc.), and on the edge of this cup the sepals as well as the petals and stamens are inserted at different levels. Finally, in the Apple, Pear, Quince, etc., the greatly hollowed-out receptacle assumes a vase-shaped form and closes over the top of the ovary, at the same time lifting the sepals, petals, and stamens above the ovary. Here the sepals are *epigynous*.

**The Corolla.**—The Corolla is the inner floral envelope, usually delicate in texture, and showing more or less brilliant colors and combinations of color. Its parts are called Petals, and when the calyx closely resembles the corolla in structure and coloring they are together called the *Perianth*. The purpose of these envelopes is to protect the reproductive organs within, and also to aid in the fertilization of the flower, as their bright colors, fragrance and saccharine secretions serve to attract pollen-carrying insects.

*Forms of the Corolla and Perianth.*—When the petals are not united with each other, the corolla is said to be *Choripetalous*, *Apopetalous* or *Polypetalous*. When more or less united, they are *Gamopetalous*, often called *Synpetalous*.

When the distinct petals are four in number, and arranged in the form of a cross, the corolla is called *Cruciform*. Example: Mustard and other plants belonging to the order *Cruciferae*.

The *Papilionaceous corolla* is so called because of a fancied resemblance to a butterfly. The irregularity in this form is very striking, and the petals bear special names: the largest one is the *vexillum*, or standard; the two beneath it the *alæ*, or wings; the two anterior, the *carina* or keel. Examples: Locust, Pea, and Clover.

*Orchidaceous* flowers are of peculiar irregularity, combining calyx

and corolla. The petal in front of stamen and stigma, which differs from the others in form and secretes nectar, is called the *Labellum*. Examples: *Cypripedium* and other Orchids.

When calyx and corolla each consist of three parts closely resembling each other in form and color, as in the Tulip and Lily, the flower is called *Liliaceous*.

The *Ligulate* or *Strap-shaped corolla* is nearly confined to the family Compositæ. It is usually tubular at the base, the remainder resembling a single petal. Examples: Marigold, and Arnica Flowers.

*Labiate*, or *Bilabiate*, having two lips, the upper composed of two petals, the lower one of three. This form of corolla gives the name to the *Labiatæ*, while in the family *Leguminosæ* this arrangement is sometimes reversed. The corolla may be either *ringent*, or gaping, as in Sage, or *personate*, when the throat is nearly closed by a projection of the lower lip, as in Snapdragon.

*Rotate*, *Wheel-shaped*, when the tube is short and the divisions of the limb radiate from it like the spokes of a wheel. Example: The Potato blossom.

*Crateriform*, *Saucer-shaped*, like the last, except that the margin is turned upward or cupped. Example: *Kalmia latifolia* (Mt. Laurel).

*Hypocrateriform*, or *Salver-shaped* (more correctly, hypocraterimorphous), when the tube is long and slender, as in Phlox or Trailing Arbutus and abruptly expands into a flat limb. The name is derived from that of the ancient Salver, or hypocraterium with the stem or handle beneath.

When of nearly cylindrical form, the corolla is *Tubular*, as in the Honeysuckle, and Stramonium.

*Funnel-form* (Infundibuliform), such as the corolla of the common Morning Glory, a tube gradually enlarging from the base upward into an expanded border or limb.

*Campanulate*, or *Bell-shaped*, a tube whose length is not more than twice the breadth, and which expands gradually from base to apex. Examples: Canterbury Bell, Harebell.

*Urceolate*, or *urn-shaped*, when the tube is globose in shape and the limb at right angles to its axis, as in the official Uva Ursi, Chamaepila and Gaultheria.

*Caryophyllaceous*, when the corolla consists of five petals, each with a long slender claw expanding abruptly at its summit into a broad limb. Examples: Carnation and other members of the Pink family.

**The Andrœcium or Stamen System.**—*The andrœcium* is the single or double whorl of male organs situated within or above the corolla. It is composed of *stamens* or *microsporophylls*.

A complete stamen consists of a more or less slender stalk portion called a *filament* and a terminal appendage called the *anther* or *micro-sorus*. The anther is generally vertically halved by an upgrowth of the filament called the *connective*, dividing the anther into two *lobes*.

**Number of Stamens.**—When few in number, stamens are said to be *definite*; when very numerous, and not readily counted, they are *indefinite*. The following terms are in common use to express their number:

*Monandrous*, for a *flower* with but one stamen.

*Diandrous*, with two stamens.

*Triandrous*, with three.

*Tetrandrous*, with four.

*Pentandrous*, having five.

*Hexandrous*, six.

*Polyandrous*, an indefinite number.

The most primitive flowers have numerous stamens but passing from these to those of more evolved families there occurs a gradual reduction from many to ten, as in *Caryophyllaceæ*, *Leguminosæ* and some *Aceraceæ*, these being in two circles. In *Malvaceæ*, *Umbelliferæ* and other Apopetalous families as well as many Sympetalæ, the number five is typical. But in *Scrophulariaceæ*, while five are developed and fertile in *Verbascum*, four with a fifth staminode (sterile stamen) are found in the allied genus *Celsia*. In *Pentstemon* there are four didynamous fertile stamens and an equally long staminode. In *Scrophularia* the fifth staminode is reduced to a petaloid flap in the posterior part of the flower. In *Linaria* this exists only as a small knob at the base of the back part of the corolla and there secretes nectar. In most *Scrophulariaceæ* the fifth stamen is entirely absent and the four stamens left are didynamous; but in *Calceolaria* two of these are rudimentary and thread-like, the other two alone

being well-developed and fertile. In *Veronica* three stamens are entirely absorbed and two only are left as fertile representatives.

**Insertion of Stamens.**—As to insertion the stamens may be:

*Hypogynous*, when inserted upon the receptacle below the base of the pistil.

*Perigynous*, when inserted on the calyx or corolla above the base of and lateral to the pistil.

*Epigynous*, when inserted above the ovary.

*Gynandrous*, when inserted upon the pistil, as in Orchids and Aristolochia.

**Proportions of the Stamens.**—The stamens may be of equal length; unequal, or of different length.

*Didynamous*, when there are two pairs, one longer than the other. Example: Snapdragon.

*Tetradynamous*, three pairs, two of the same length, the third shorter. Example: Mustard.

**Connation of Stamens.**—Terms denoting connection between stamens are:

*Monadelphous* (in one brotherhood), coalescence of the filaments into a tube. Example: *Lobelia*.

*Diadelphous* (in two brotherhoods), coalescence into two sets. Example: *Glycyrrhiza*.

*Triadelphous*, with filaments united into three sets. Example: St. John's Wort.

*Polyadelphous*, when there are several sets or branched bundles. Example: Orange.

*Syngenesious*, when the anthers cohere. Example: *Compositæ*.

**Color of Stamens.**—In most species the color of these organs is seldom pronounced owing to their delicate structure. It varies from greenish-yellow to yellow to white, through pink, pinkish-red, red, purple, purple-blue to blue. It is yellow, for instance, in Sassafras, Cucumber and Golden Club; greenish-yellow, yellow to red in Maples; yellow-pink to pink and pinkish-red in some Mallows; in *Azalea amena* the filaments are crimson-purple and the anthers, purple-blue; in the genus *Scilla* both filaments and anthers are blue.

**Gross Structure and Histology of the Filament.**—The filament may be cylindrical as in the Rose, awl-shaped as in Tulip, flat and with



a dilated base as in the Harebell, three-toothed as in Garlic, appendiculate, when it bears an appendage as in *Chatostoma*, *Alyssum*, etc. The filament is covered with a protective epidermis containing stomata. Beneath this is a soft, loose cellular tissue, the mesophyll, and in the center a small vascular bundle, the pathway of food from the floral axis to the anther. In some cases the single bundle may split into two or three bundle parts.

**Gross Structure and Histology of the Anther.**—Each staminal leaf (microsporophyll) bears a special development or appendage as a rule on its extremity which is the *anther* or *microsoros*. This consists, fundamentally, of a median prolongation of the filament equal to the connective or placenta. This develops on either side a quantity of indusial tissue that grows out to form a covering substance that protects and carries two microsporangia on either side. An anther therefore consists of a median *connective* or placenta, producing on either side two *anther lobes* or indusial expansions. Each anther lobe encloses two pollen sacs or *microsporangia* which, in some cases, remain distinct up to the dehiscence (splitting open) of the anther. Thus in *Butomus*, the anthers show four pollen chambers up to the time of dehiscence. Again in various species of *Lauraceæ*, the anthers remain four lobed and dehisce by four recurved lids. But in the great majority of Angiosperms each pair of pollen sacs fuse before dehiscence, owing to the breaking down of the partition between them, and so, at that time, show two-celled anthers. Still more rarely the anthers may be two-celled in their young state and by the breaking down of the partition become one-celled, e.g., *Malvaceæ*.

Externally the mature anther is bounded by an *exothecium* or epidermis, often swollen, where lines of dehiscence occur, which may develop stomata, also hairs. Within it is a combined layer or set of one to often two or three, sometimes five or six cell layers (Agave, etc.) of indusial and sporangial cells, the *endothecium*. The outermost one to three layers of this become spirally, annularly or stellately thickened to form the elastic tissue of the anther, which, by pressure against the delicate epidermis or exothecium, causes ultimate rupture of the anther wall. Within the innermost endothelial layer, bounding each sporangium, is the *tapetum*, a single-celled layer. This, near the time of dehiscence, undergoes breaking down or absorption by developing

*pollen* or microspore cells. Filling the cavities of the four sporangia are the mature pollen grains. The connective shows in or near its center a vascular bundle with xylem uppermost and phloem downward, surrounded by thin-walled cellular tissue, from which the indusial and sporangial substance has matured by extension.

**Anther Dehiscence.**—This is the breaking open of the anther to discharge the pollen.

When fully ripe the dividing partition between each pair of sporangia usually becomes thinned, flattened and ultimately breaks down,

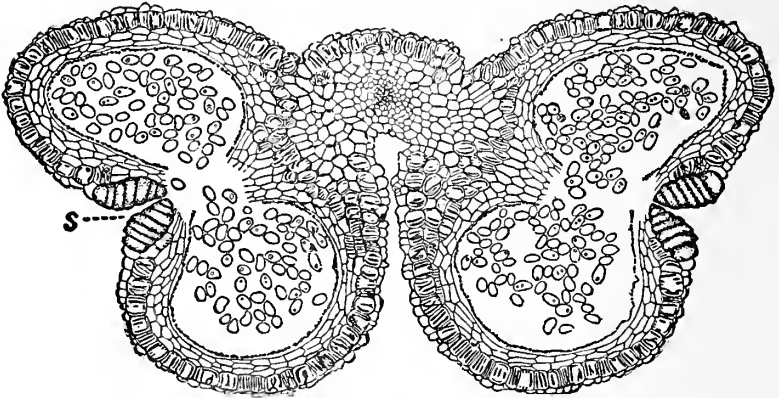


FIG. 66.—Cross-section of a mature lily anther. The pairs of pollen chambers unite to form two pollen sacs, filled with pollen grains; *s*, modified epidermal cells at line of splitting. (From a Text-book of Botany by Coulter, Barnes, and Cowles. Copyright by the American Book Company, Publishers.)

while the elastic and resistant endothecium, steadily pushing against the more delicate and now shrinking exothecium causes rupture where endothecium is absent, namely along opposite lines of the anther wall. Thus arises a line of anther dehiscence called *longitudinal anther dehiscence* on either side of the anther sacs. In the division *Solanææ* of the family *Solanaceæ* which includes Belladonna, in some of the *Ericaceæ* as *Rhododendron* and *Azalea*, etc., the anthers dehisce by small apical pores from which the pollen is shed. This kind of dehiscence is called *apical porous dehiscence*. Again, in *Lauraceæ* and *Berberidaceæ*, the anthers dehisce by recurved valves. This is called *valvular dehiscence*.

Moreover, in *Malvaceæ* the originally longitudinal anther is divided internally by a partition. It gradually swings on the filament so that eventually the anther is transverse and the partition becomes absorbed, thus becoming a one-celled anther with *transverse dehiscence* in its mature state.

**Development of the Anther.**—Each stamen originates as a knob-like swelling from the receptacle between the petals and carpels. This swelling represents mainly future soral (anther) tissue. The filament develops later. When such a young sorus or anther is cut across and examined microscopically, it shows a mass of nearly similar cellular tissue in which the first observable changes are the following:

The surface dermatogen cells become somewhat flattened and regular to form the future epidermis or exothecium of the anther. About the same time some cells, by more rapid division in the middle of the anther substance, give rise to the elements of the vascular bundle in the connective. Then, along four longitudinal tracts, rows of cells remain undivided or only divide slowly as they increase in size and around them cells divide and redivide to form the future endothelial and covering tissue to the four sporangia. Next, the four sporangial tracts of undivided cells cut off from their outer surfaces a layer of enveloping cells, the *tapetum*. This consists of richly protoplasmic cells that form a covering to the *spore mother-cells* within. Each spore mother-cell undergoes division and redivision into four spore daughter-cells at the same time that reduction in the chromatin substance takes place in these cells. Thus originate *tetrads* (groups of four) of *spore daughter-cells* inside spore mother-cell wall. These continue to enlarge, press against the mother-cell wall which becomes converted into mucilage and each of the tetrad cells becomes in time a mature *microspore* or *pollen grain*.

During this time the entire anther is growing in size, the cells of the endothecium in one or more layers becomes thickened by lignin deposits to form a mechanical *endothecium*; the *tapetum* gradually breaks down and appears only at length as an irregular layer around the maturing pollen cells. When the anther is finally ripe the partition between each pair of microsporangia becomes narrowed, flattened and ruptured and thus numerous microspores or pollen grains

fill two cavities, one on either side of the connective. The microspores or pollen grains at first show only a thin clear cellulose layer, but from this, by a differentiation of the exterior film, the *exospore* layer becomes cut off. This becomes cuticular. The cellulose inner layer (*endospore*), remains unaltered. In the development of the exospore, one to several deficiencies are usually left in it through which the endospore may protrude later as the rudiment of the pollen tube.

*Attachment of Anther.*—The attachment of the anther to the filament may be in one of several ways, as follows:

*Innate*, attached at its base to the apex of the filament.

*Adnate*, adherent throughout its length.

*Versatile*, when the anther is attached near its center to the top of the filament, so that it swings freely. The adnate and versatile are *introrse* when they face inward, *extrorse* when they face outward.

**Pollen.**—The pollen grains or microspores vary in form for different species and varieties and while they are averagely constant for these, nevertheless many exceptions have been recorded. The following are some of the commoner forms:

*Four Spore Daughter-cells*, hanging together as in the Cat Tail (*Typha*) forming a pollen grain.

*Elongated*, simple pollen grains as in *Zostera*.

*Dumb-bell-shaped*, as the pollen of the Pines.

*Triangular*, as in the *Ænotheras*.

*Echinate*, as in the *Malvaceæ*.

*Spherical*, as in *Geranium*, Cinnamon and Sassafras.

*Lens-shaped*, as in the Lily.

*Spinose*, as in the *Compositæ*.

*Barrel-shaped*, as in *Polygala*.

Under the microscope the immature pollen grain generally consists of two membranes, an outer firmer one called the *exospore*, which may be variously marked and which possesses deficiencies in the form of "pores" or "clefts," and an inner delicate cellulose membrane called the *endospore*, which surrounds a protoplasmic interior in which are imbedded a nucleus, oil droplets and frequently starch or protein.

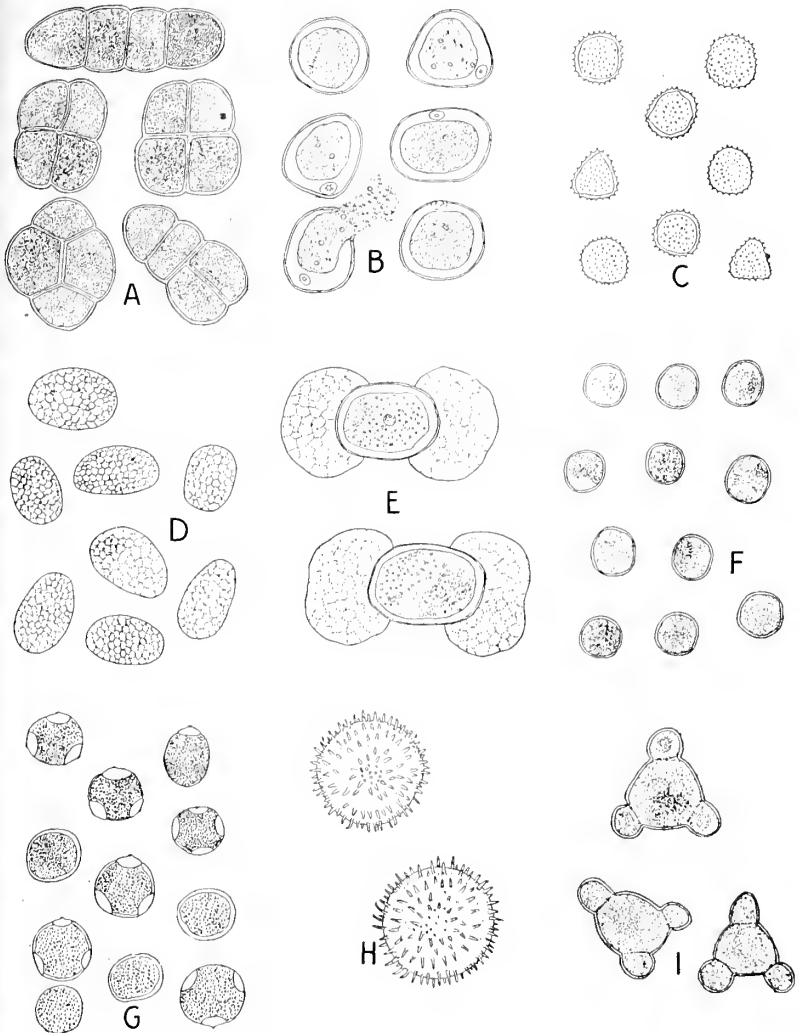


FIG. 67.—Various forms of pollen grains. Pollen from *Typha latifolia* (A), *Zea mays* (B), *Ambrosia elatior* (C), *Lilium philadelphicum* (D), *Pinus* (E), *Ranunculus bulbosus* (F), *Carpinus caroliniana* (G), *Althaea rosea* (H), *Oenothera biennis*, (I). All highly magnified. Drawing by Hogstad.

*Pollinia*.—These are agglutinated pollen masses which are common to the *Orchidaceæ* and *Asclepiadaceæ*.

The pollen of many plants, notably certain species of *Compositæ*, *Gramineæ* and *Rosaceæ*, has been shown to be responsible for "Hay Fever." At the present time serums, extracts and vaccines are manufactured from pollen to be used in the treatment of this disease.

**The Gynœcium or Pistil System.**—This is the female system of organs of flowering plants. It may consist of one or more modified leaves called carpels. Each *carpel* or *megasporophyll* is a female organ of reproduction. In the Spruce, Pine, etc., it consists of an open leaf or scale which bears but does not enclose the *ovules*. In angiosperms it forms a closed sac which envelops and protects the *ovules*, and when complete is composed of three parts, the ovary or hollow portion at the base enclosing the *ovules* or rudimentary seeds, the *stigma* or apical portion which receives the pollen grains, and the *style*, or connective which unites these two. The last is non-essential and when wanting the stigma is called sessile. The carpel clearly shows its relations to the leaf, though greatly changed in form. The lower portion of a leaf, when folded lengthwise with the margins incurved, represents the *ovary*; the infolded surface upon which the ovules are borne is the placenta, a prolongation of the tip of the leaf, the stigma, and the narrow intermediate portion, the style. *A leaf thus transformed into an ovule-bearing organ is called a carpel.* The carpels of the Columbine and Pea are made up of single carpels. In the latter the young peas occupy a double row along one of the sutures (seams) of the pod. This portion corresponds to the infolded edge of the leaf, and the pod splits open along this line, called the ventral suture.

Dehiscence, or the natural opening of the carpel to let free the contained seeds, takes place also along the line which corresponds to the mid-rib of the leaf, the dorsal suture.

The gynœcium or Pistil may consist of a number of separate carpels, as in the buttercup or *Nymphaea* flowers, when it is said to be *apocarpous*, or the carpels composing it may be united together to form a single structure, as in the flowers of Belladonna and Orange, when it is called *syncarpous*.

If the pistil is composed of one carpel, it is called *monocarpellary*;

if two carpels enter into its formation, it is said to be *dicarpellary*; if three, *tricarpellary*; if many, *polycarpellary*.

*Compound Pistils* are composed of carpels which have united to form them, and therefore their ovaries will usually have just as many cells (locules) as carpels. When each simple ovary has its placenta, or seed-bearing tissue, at the inner angle the resulting compound ovary has as many axile or central placentæ as there are carpels, but all more or less consolidated into one. The partitions are called dissepiments and form part of the walls of the ovary. If, however, the carpels are joined by their edges, like the petals of a gamopetalous corolla, there will be but one cell, and the placenta will be parietal, or on the wall of the compound ovary.

The *ovules* or megasporia are transformed buds, destined to become seeds in the mature fruit. Their number varies from one to hundreds. In position, they are erect, growing upward from the base of the ovary, as in the Compositæ; ascending, turning upward from the side of the ovary or cell; pendulous, like the last except that they turn downward; horizontal, when directed straight outward; suspended, hanging perpendicularly from the top of the ovary.

In Gymnosperms the ovules are naked; in Angiosperms they are enclosed in a seed vessel.

A complete angiospermous seed ovule which has not undergone maturation consists of a *nucellus* or body; two coats, the outer and inner *integuments*; and a *funiculus*, or stalk. Within the nucellus is found the *embryo sac* or *megaspore* containing protoplasm and a nucleus.

The coats do not completely envelop the nucellus, but an opening at the apex, called the *foramen* or *micropyle* admits the pollen tube. The vascular plexus near the point where the coats are attached to each other and to the nucellus is called the *chalaza*. The *hilum* marks the point where the funiculus is joined to the ovule, and if attached to the ovule through a part of its length, the adherent portion is called the *raphe*. The shape of the ovule may be *orthotropous*, or straight; *campylotropous*, bent or curved; *amphitropous*, partly inverted; and *anatropous*, inverted. The last two forms are most common. A campylotropous ovule is one whose body is bent so that the hilum and micropyle are approximated.

*The Placenta.*—The placenta is the nutritive tissue connecting the ovules with the wall of the ovary. The various types of placenta arrangement (placentation) are grouped according to their relative complexity as follows: (1) Basilar, (2) Sutural, (3) Parietal, (4) Central, (5) Free Central.

Basilar placentation is well illustrated in the *Polygonaceæ* (Smart Weed, Rhubarb, etc.) in *Piper* and *Juglans*. Here, at the apex of the axis and in the center of the ovarian base, arises a single ovule from a small area of placental tissue.

Sutural placentation is seen in the *Leguminosæ* (Pea, Bean, etc.). Here each carpel has prolonged along its fused edges two cord-like placental twigs, from which start the funiculi or ovule stalks.

Parietal placentation is seen in *Gloxinia*, *Gesneria*, *Papaver*, etc. Here we find two or more carpels joined and placental tissue running up along edges of the fused carpels bearing the ovules.

Central or axile placentation is seen in *Campanulaceæ* (Lobelia), where the two, three, or more carpels have folded inward until they meet in the center and in the process have carried the originally parietal placenta with them. This then may form a central swelling bearing the ovules over the surface.

Free Central placentation occurs perfectly in the *Primulaceæ*, *Plantaginaceæ* and a few other families. In this the carpels simply cover over or roof in a central placental pillar around which the ovules are scattered.

**Style.**—The style is the portion of the carpel which connects the stigma with the ovary. It is usually thread-like but may also be considerably thickened. It frequently divides into branches in its upper part. These are called *style arms*. As many style arms as carpels may be present. In the one-carpelled pistil of some *Leguminosæ*, the usually bent-up style is the tapered prolongation of a single flower. Again, in the apocarpous carpels of many flowers of the *Ranunculaceæ*, each carpel bears a short to long stylar prolongation. When the carpels, however, are syncarpous the common styles tend to become more or less fused but usually show lobes, clefts or style arms at their extremities that indicate the number of carpels in each case which form the gynoecium.

In some plants remarkable variations from the typical stylar



development may occur. Thus, in *Viola*, the end of the style is a swollen knob on the under surface of which is a concave stigma with a flap or peg. In the genus *Canna* the style is an elongate blade-like flattened body with a sub-terminal stigma. In forms of the *Campanulaceæ* the style is closely covered with so-called collecting hairs. On these the anthers deposit their pollen at an early period before the flowers have opened. Later, when the flowers open, insects remove the pollen after which the collecting hairs wither. The stigmas then curl apart to expose their viscid stigmatic hairs. In this instance there are two distinct and at separate times functioning hairs on the stylar prolongation, viz.: (a) *collecting stylar hairs*, functioning for pollen collection and distribution; and (b) *stigmatic hairs* for pollen reception from another flower. In *Vinca* the style swells near its extremity into a broad circular stigma and then is prolonged into a short *column* bearing a tuft of hairs that prevents the entrance of insect thieves into the flower. In the genus *Iris* the common style breaks up at the insertion of the perianth into three wide petaloid style arms. Each of these bifurcates at its extremity. On the lower or outer face of this is a transverse flap that bears the stigmatic papillæ. In *Physostigma* the style enlarges at its extremity into a flap-like swelling which bears a narrow stigmatic surface. Finally in *Sarracenia* the single style of the five-carpelled pistil enlarges above into a huge umbrella-like portion with five radiating ribs. At the extremity of each bifid end of each rib is a minute peg-like stigmatic surface.

**The Stigma.**—This is usually a viscid papillose surface of greater or less expanse functioning for pollen reception. In wind-pollinated flowers such as the grasses, the stigmas are the numerous feathery hairs which cover the ends of the styles and intended to catch flying pollen grains. In animal-pollinated flowers, the stigmas are usually small restricted knobs, lines or depressions. The stigmatic papillæ vary in size in different plants and even may vary on different individuals of the same species. Thus in the long styles of *Primula*, the stigmatic papillæ are elongated columnar hair-like structures, whereas in the short styles of short-styled flowers the papillæ are small knob-like cellular swellings.

## POLLINATION

Pollination is the transfer of pollen from anther to stigma and the consequent germination thereon. It is a necessary step to fertilization.

When the pollen is transferred to the stigma of its own flower the process is called *Close* or *Self-pollination*; if to a stigma of another flower, *Cross-pollination*. If fertilization follows, these processes are termed respectively, *Close or Self-fertilization* and *Cross-fertilization*. Close-fertilization means in time ruination to the race and happily is prevented in many cases by (a) the stamens and pistils standing in extraordinary relation to each other, (b) by the anthers and pistils maturing at different times, (c) by the pollen in many cases germinating better on the stigma of another flower than its own.

The agents which are responsible for cross-pollination are the wind, insects, water currents, small animals, and man.

*Wind-pollinated* flowering plants are called *Anemophilous*; their pollen is dry and powdery, flowers inconspicuous and inodorous, as in the Pines, Wheat, Walnut, Hop, etc.

*Insect-pollinated plants* are called *Entomophilous*. These, being dependent upon the visits of insects for fertilization, possess brilliantly colored corollas, have fragrant odors, and secrete nectar, a sweet liquid very attractive to insects which are adapted to this work through the possession of a pollen-carrying apparatus. Example: Orchids.

*Plants pollinated through the agency of water currents* are known as *Hydrophilous*. To this class belong such plants as live under water and which produce flowers at or near the surface of the same. Example: Sparganium.

*Animal-pollinated plants* are called *Zoöphilous*. Some plants like the Nasturtium and Honeysuckle are pollinated by humming birds.

Before the pollen grain has been deposited upon the stigma and during its germination thereon, a series of events affecting both the pollen grain and the embryo sac occur which result in the ultimate formation of the male and female gametophytes.

**Maturation of the Pollen Grain and Formation of the Male Gametophyte.**—The substance of the microspore (pollen grain) divides into two cells, the *mother* and *tube cells* of the future male

gametophyte. The nucleus of the mother-cell divides to form two sperm nuclei. Within the tube cell is found a tube nucleus embedded in protoplasm. Upon germinating the partition disappears and the thin endospore, carrying within it the protoplasm in which are embedded the tube nucleus and two sperm nuclei, penetrates through a deficiency of the exospore. The contents of the pollen grain at this stage is called the *male gametophyte*.

**Maturation of the Embryo Sac and Formation of the Female Gametophyte.**—The *nucleus* of the megaspore or embryo sac undergoes division until eight *daughter-nuclei* are produced which are separated into the following groups:

(a) Three of these nuclei occupy a position at the apex, the lower nucleus of the group being the egg or ovum, the other two nuclei being the *synergids* or *assisting nuclei*.

(b) At the opposite end of the sac are three nuclei known as the *antipodals* which apparently have no special function.

(c) The two remaining nuclei (*polar nuclei*) form a group lying near the center of the embryo sac which unite to form a single *endosperm* nucleus from which, after fertilization, the endosperm or nourishing material is derived. This stage of the embryo sac constitutes the *female gametophyte*.

**Fertilization in Angiosperms.**—After the pollen grain reaches the stigma, the viscid moisture of the stigma excites the outgrowth of the male gametophyte which bursts through the coats of the pollen grain forming a pollen tube. The pollen tube, carrying within its walls two sperm nuclei and one tube nucleus, penetrates through the loose cells of the style until it reaches the micropyle of the ovule, then piercing the nucellus, it enters the embryo sac. The tip of the tube breaks and one of the sperm nuclei unites with the egg to form the *öospore*. The öospore develops at once into an embryo or plantlet, which lies passive until the seed undergoes germination. The other sperm nucleus unites with the previously fused polar nuclei to form the endosperm nucleus which soon undergoes rapid division into a large number of nuclei that become scattered about through the protoplasm of the embryo sac. These accumulate protoplasm about them, cells walls are laid down, *endosperm* resulting.

## THE FRUIT

The fruit consists of the matured pistil (carpel or carpels) and contents, or ovarian portion thereof, but may include other organs of the flower which frequently are adnate to and ripen with it. Thus in the Apples, Pears and Quinces, the receptacle becomes thick and succulent, surrounds the carpels during the ripening process and forms the edible portion of these fruits. In Dandelion, Arnica, and many other members of the *Compositæ*, the modified calyx or *pappus* adheres to the ovary during its maturation into the fruit and renders the fruit buoyant. In *Gaultheria* the calyx becomes fleshy, surrounds the ovary, reddens, and forms the edible part of the fruit. In *Physalis* the calyx enlarges considerably and encloses the ovary in an inflated colored bladder. Involucres frequently persist around and mature with the fruits. These may be membranous as in *Anthemis*, *Matricaria* and other *Compositæ*, leathery and prickly as in the Chestnuts, scaly woody cups (cupules) as in the Oaks, or foliaceous cups as in the Filberts. Occasionally, as in the Fig, Osage Orange, Mulberry, etc., the fruit may consist of the ripened flower cluster or inflorescence.

## FRUIT STRUCTURE

The *Pericarp*, or *seed vessel*, is the ripened wall of the ovary, and in general the structure of the fruit wall resembles that of the ovary, but undergoes numerous modifications in the course of development.

The number of cells of the ovary may increase or decrease, the external surface may change from soft and hairy in the flower to hard, and become covered with sharp, stiff prickles, as in the *Datura Stramonium* or Jamestown weed. Transformations in consistence may take place and the texture of the wall of the ovary may become hard and bony as in the Filbert, leathery, as the rind of the Orange, or assume the forms seen in the Gourd, Peach, Grape, etc.

Frequently the pericarp consists for the most part of other elements than the ripened ovarian wall and is then termed a *pseudocarp* or *anthocarp*. The pericarp consists of three layers of different texture, viz.: *epicarp*, *mesocarp* and *endocarp*. The epicarp is the outer layer. The mesocarp the middle, and the endocarp the inner

layer. When the mesocarp is fleshy, as in the Peach, it is called the *sarcocarp*.

When the endocarp within the sarcocarp is hard, forming a shell or stone, this is termed a *putamen*.

**Sutures.**—The *ventral suture* is a line formed by the coherent edges of a carpellary leaf. The *dorsal suture* is the mid-rib of the carpel. *Parietal sutures* are lines or furrows frequently visible on the walls of fruits, formed by the ripening of a compound ovary. They occur between its dorsal sutures and indicate the places of union between adjacent septa or of two parietal placenta.

**Valves.**—These are the parts into which the mature fruit separates to permit the escape of the seeds. Depending upon the number of these the fruit is said to be *univalved*, *bivalved*, *trivalved*, etc.

**Dehiscence.**—This is the opening of the pericarp to allow the seeds to escape.

Fruits are either *Dehiscent* or *Indehiscent* according as they open to discharge their seeds spontaneously when ripe (dehiscent), or decay, thus freeing the seeds, or retain their seeds, the embryo piercing the pericarp in germination (*indehiscent*). Dehiscent fruits open regularly, or normally, when the pericarp splits vertically through the whole or a part of its length, along sutures or lines of coalescence of contiguous carpels. Legumes usually dehisce by both sutures. Irregular or abnormal dehiscence has no reference to normal sutures, as where it is *transverse* or *circumscissile*, extending around the capsule either entirely or forming a hinged lid, as in *Hyoscyamus*, or detached.

*Dehiscence* is called *porous* or *apical* when the seeds escape through pores at the apex, as in the Poppy; *valvular*, when valve-like orifices form in the wall of the capsule. *Valvular dehiscence* is *septicidal*, when the constituent carpels of a pericarp become disjoined, and then open along their ventral suture. Example: *Colchicum*; *loculicidal*, dehiscence into loculi, or cells, in which each component carpel splits down its dorsal suture, and the dissepiments remain intact. Example: *Cardamon*; *septifragal dehiscence*, a breaking away of the valves from the septa or partitions. Example: *Orchids*.

**Classification of Fruits** (according to structure).—*Simple fruits* result from the ripening of a single pistil in a flower.

*Aggregate fruits* are the product of all the carpel ripenings in one flower, the cluster of carpels being crowded on the ripened receptacle forming one mass, as in the Raspberry, Blackberry, and Strawberry.

*Multiple fruits* are those which are the product of the ripening of a flower cluster instead of a single flower.

Simple and Compound fruits are either Dry or Fleshy. The first may be divided into Dehiscent, those which split open when ripe; and Indehiscent, those which do not.

### Simple Fruits:

- |           |   |                               |
|-----------|---|-------------------------------|
| Dry       | { | I. Capsular (dehiscing).      |
|           |   | II. Schizocarpic (splitting). |
|           |   | III. Achenial (indehiscent).  |
| Succulent | { | IV. Baccate (berries).        |
|           |   | V. Drupaceous (stone fruits). |

The **capsular** fruits include all of those, whether formed of one or more carpels, which burst open to let seeds escape.

**Schizocarpic** or splitting fruits are those in which each carpel or each half carpel (in Labiatae) splits asunder from its neighbor and then falls to the ground. The split portion is one-seeded.

**Achenial** fruits are dry, one-celled, one-seeded and indehiscent at the time of final ripening.

**Baccate** fruits are such in which the endocarp always and the mesocarp usually becomes succulent and so the seeds lie in the pulp formed by the endocarp or endocarp and mesocarp combined.

**Drupaceous** fruits are those in which the endocarp is always fibrous or stony in consistence, while the mesocarp is more or less succulent. The endocarp may become cuticularized as in the Apples. The mesocarp may form stone cells lying in the midst of soft parenchyme cells as in Pears; it may become hardened and thickened by lignin deposits to form fibers as in the Cocomnut, or it may become swollen and soft-succulent as in Peaches, Cherries, etc.

**I. Capsular Fruits.**—These may be simple, when composed of one carpel as the follicle and legume, or compound, when composed of two or more carpels as the capsule, pyxis, regma, siliqua or silicule.

The **Follicle** or pod is a dry, simple capsular fruit formed of a

single carpel which dehisces by one suture. This is usually the ventral suture as in *Aconite*, *Staphisagria*, *Larkspur* and some other *Ranunculaceæ*, but may be the dorsal suture as in *Magnolia*.

A **Legume** is a dry simple capsular fruit formed of a single carpel and dehiscent by both ventral and dorsal sutures. Examples: Peas, Beans, etc. The legume is typical of most *Leguminosæ*.

A **Capsule** is a fruit formed of two or more carpels which dehisce longitudinally or by apical teeth or valves. Examples: *Cardamon*, Poppy, *Iris*, etc.

A **Pyxis** or **Pyxidium** is a capsular fruit formed of two or more carpels that dehisce transversely. Examples: *Hyoscyamus*, *Portulaca*. The upper portion forms a lid which fits upon the lower pot-like portion.

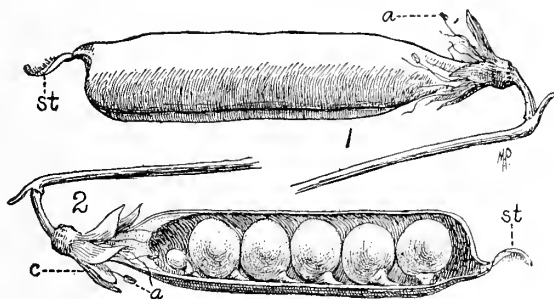


FIG. 68.—Legume of the edible pea (*Pisum sativum*). *a*, anther; *c*, calyx; *st*, stigma. (Gager.)

A **Regma** is a capsular fruit of two or more carpels that first splits into separate parts and then each of these dehisces. This type of fruit is typical of *Hura crepitans* (Sandbox), *Pelargonium* and *Geranium*.

A **Siliqua** is a long slender one or two-celled capsule, often with a spurious membranous septum (when two-celled) and two persistent parietal placentæ, the valves opening from below upward. Examples: *Chelidonium* and Wallflower.

A **Silicule** is a short siliqua in which the length is never much greater than the breadth. Example: *Cochlearia*.

II. **Schizocarpic Fruits**.—A **Carcerulus** or **Nutlet** is the typical fruit of the *Labiatae* but is also seen in the *Borraginaceæ*. The ovary

that has become four-celled at the time of flowering matures into four little pieces which split asunder lengthwise. Each split part is composed of one-half of a ripened carpel.

A **Cremocarp** is the characteristic splitting fruit of the Umbelliferæ family. It consists of two inferior akenes or mericarps separated from each other by a forked stalk called a *carpophore*. These mericarps usually cling to the forks of the carpophore for a time after the cremocarp splits, but sooner or later fall.

A **Samara** is a winged splitting fruit. It may be one-carpelled as in the Elm, Ash, Tulip Poplar and Wafer Ash or two-carpelled as in the Maples.

A **Lomentum** or **Loment** is a splitting fruit that splits transversely into one-seeded portions. Seen in *Cruciferæ*, in *Entada scandens*, *Cathartocarpus Fistula*, *Desmodium*, etc. of *Leguminosæ*.

III. **Achenial Fruits** (all indehiscent).—The **Akene** is a dry one-chambered, indehiscent fruit, in which the pericarp is firm and may or may not be united with the seed, the style remaining in many cases as an agent of dissemination. The latter may be long and feathery as in *Clematis* or be hooked. Examples of akenes: Fruits of the *Compositæ*, *Anemone*, etc. The *Hip* of the Roses consists of a number of akenes in a ripened concave receptacle.

The **Utricle** is like the akene, except that the pericarp is loose and bladder-like. Example: *Chenopodium*.

A **Caryopsis** or **Grain** is similar to an akene but differs from it by the pericarp being always fused with the seed coat. This fruit is more likely than any other to be mistaken for a seed. Examples: Wheat, Corn, Barley, Oats and other members of the *Graminaceæ*.

A **Nut** or **Glans** is a one-celled, one-seeded fruit with a leathery or stony pericarp. Examples: Oaks, Beeches, Chestnuts, Alders and Palms.

IV. **Baccate Fruits** (Succulent fruits in which the endocarp is always succulent and the mesocarp sometimes).—The **Berry** is a small fleshy fruit with a thin membranous epicarp and a succulent interior in which the seeds are imbedded. Examples: Capsicum, Tomato, Belladonna, Grape, Currant, etc.

An **Uva** is a berry from a superior ovary. Examples: Belladonna, Egg-plant, Tomato.



A **Bacca** is a berry from an inferior ovary. Examples: Gooseberry, Honeysuckle, Currant.

The **Pepo** or **Gourd Fruit** is a baccate fruit of large size which has developed from an inferior ovary. It is fleshy internally and has a tough or very hard rind. Examples: Fruits of the *Cucurbitaceæ* and the Banana.

The **Hesperidium** is a large thick-skinned succulent fruit with seeds embedded in the pulp but from a superior ovary. Examples: Orange, Grape-fruit, Lemon, etc. In each of these there is to be noted a glandular leathery epicarp, a sub-leathery mesocarp and an endocarp in the form of separate carpels. From the endocarp hairs grow inward into the carpellary cavities and become filled with succulence. The seeds lie amid the hair cells.

**V. Drupaceous Fruits** (Succulent fruits in which the mesocarp is more or less succulent, but the endocarp leathery or stony).—A **Drupe** is a one-celled, one-seeded drupaceous fruit such as the fruit of the Plum, Peach, Prune, Sabal, Rhus, Piper, Cherry, etc., whose endocarp or putamen is composed wholly of stone cells or stone cells and sclerenchyme fibers.

The **Pome** is a fleshy drupaceous fruit, two or more celled with fibrous or stony endocarp, the chief bulk of which consists of the adherent torus. Quince, Apple and Pear are examples. The carpels constitute the core, and the fleshy part is developed from the torus.

**Aggregate Fruits.**—An **Etærio** consists of a collection of little drupes on a torus of a single flower. Examples: Raspberry, Blackberry, etc.

**Multiple Fruits.**—The **Syconium** is a multiple fruit consisting of a succulent hollow torus enclosed within which are akene-like bodies, products of many flowers. Example: Fig.

The **Sorosis** is represented by the Mulberry, Osage Orange, etc., the grains of which are not the ovaries of a single flower, as in the Blackberry, but belong to as many separate flowers. In the Pineapple all the parts are blended into a fleshy, juicy, seedless mass, and the plant is propagated by cuttings.

The **Strobile** or **Cone** is a scaly, multiple fruit consisting of a scale-bearing axis, each scale enclosing one or more seeds. The

name is applied to the fruit of the Hop, and also to the fruit of the *Coniferæ* in which the naked seeds are borne on the upper surface of the woody scales.

A **Galbalus** is a more or less globular multiple fruit formed of fleshy connate scales, as in Juniper.

**Histology of a Capsule, Vanilla.**—The Vanilla fruit is a one-celled capsule formed by the union of three carpellary leaves and dehiscing by two unequal longitudinal valves.

**Microscopic Appearance of a Transverse Section.**—Passing from periphery toward the center, the following structures present themselves:

1. **Epicarp**, consisting of *epidermis* and *hypodermis*. The *epidermis* consists of a layer of thick-walled epidermal cells whose outer walls show the presence of a thin yellow cuticle. Stomata are present in this tissue. The epidermal cells contain protoplasm and brownish bodies. Some also contain small prisms of calcium oxalate and a few, vanillin crystals. The *hypodermis* is composed of one to several layers of collenchymatic cells with dark-colored contents. Its cells are somewhat larger than those of the epidermis and thicker-walled.

2. **Mesocarp**, a broad region of somewhat loosely arranged large, thin-walled parenchyma cells becoming smaller in the inner zone of this region. Most of these cells contain brownish contents but some possess long raphides of calcium oxalate. If the section be mounted in phloroglucin solution (5 per cent.) and a drop of strong sulphuric acid is added, a carmine-red color will be observed showing the presence of vanillin in this region. Several closed collateral bundles will be seen coursing through the mesocarp.

3. **Endocarp**, an irregular line of inner epidermal cells which is differentiated into two regions, the interplacental region and the placental region. The interplacental (inner) epidermis shows its cells elongated into numerous thin-walled glandular hairs which contain an abundance of balsam; the placental region covers the six bifid *placentæ* which extend into the cavity of the capsule. Its (inner) epidermis is composed of mucilaginous cells.

4. **Seeds.**—These are minute blackish bodies attached to the placental twigs of the *placentæ*. Some of them may have been torn off in cutting the section.

**Histology of a Typical Mericarp, *Foeniculum*.**—This five-angled fruit, in transverse section, shows a concave commissural and convex dorsal surface. Passing from the surfaces toward the center we note:

1. *Epicarp*, or outer covering tissue, composed of colorless epidermal cells and small stomata. The epidermal cells in cross-section appear rectangular, while in surface view they are both polygonal and rectangular.

2. *Mesocarp*, of several layers of thin-walled colorless isodiametric cells, beneath which are two to several additional layers of thicker-walled cells with brownish walls. Through the angles or

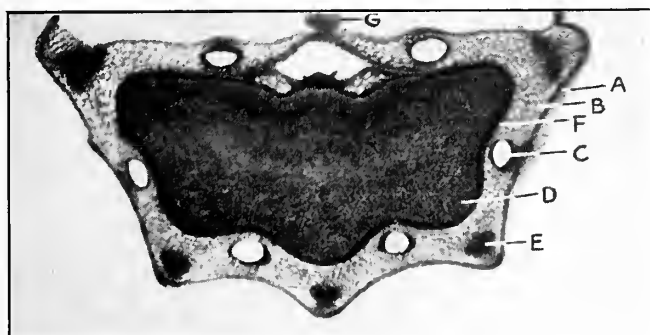


FIG. 69.—Photomicrograph of a transverse section of a mericarp of *Foeniculum vulgare*, showing epicarp (A), mesocarp (B), endocarp (F), vitta (C), endosperm of seed (D), carpophore (G) and fibro-vascular bundle in primary rib (E). (Highly magnified).

rib portions of the mesocarp extend the fibro-vascular bundles. Between each fibro-vascular bundle and the tip of each rib will be found a zone of collenchyma cells. In the mesocarp between each two ribs on the dorsal side occurs a single *vitta* or oil tube which is lined with a layer of brownish polygonal cells. These vittæ contain the official oil of fennel. Two vittæ generally occur in the mesocarp of the commissural side although four are reported to have been found in this region of some fennel fruits.

3. *Endocarp*, a narrow layer of cells, transversely elongated, except over the regions of bundles where they may be seen elongated in several directions.

4. *Spermoderm* or *Seed Coat*, consisting of a layer of somewhat broadened epidermal cells attached to the endocarp and several layers of collapsed cells which are only well defined in the region of the *raphe*.

5. *Endosperm*, a central mass of more or less polygonal cells containing aleurone grains and oil globules. Each aleurone grain contains a rosette aggregate of calcium oxalate and one or two globoids.

6. Embryo, embedded in the endosperm of the upper region of the seed.

## THE SEED

A *seed* is a matured megasorus (ovule) borne by the sporophyte of a spermatophytic plant, enclosing a megaspore (embryo sac) within which a fertilized egg of the succeeding gametophyte generation has segmented to form a new sporophyte plant. The purpose of the seed is to insure the continuation and distribution of the species. Like the ovule, it consists of a nucellus or kernel enclosed by integuments, and the descriptive terms used are the same. The seed coats, corresponding to those of the ovule, are one or two in number. If but one seed coat is present it is termed the *spermoderm*. If two are present, the outer one is called the *testa*, and the inner one the *tegmen*. The *testa*, or outer seed shell, differs greatly in form and texture. If thick and hard, it is crustaceous; if smooth and glossy, it is polished; if roughened, it may be pitted, furrowed, hairy, reticulate, etc.

The *testa* may often present outgrowths or seed appendages whose functions are to make the seeds buoyant, whereby they may be disseminated by wind currents. Examples of these are seen in the Milkweed, which has a tuft of hairs at one end of the seed called a *Coma*, and in the official ***Strophanthus***, which has a long bristle-like appendage attached to one end of the seed and called an *awn*. The wart-like appendage at the hilum or micropyle, as in Castor Oil Seed, is called the *Caruncle*.

The *tegmen* or inner coat surrounds the nucellus closely and is generally soft and delicate.

A third integument, or accessory seed covering outside of the *testa*,

is occasionally present and is called the *Aril*. Example: *Euonymus* (succulent).

When such an integument arises from the dilatation of the micropyle of the seed, as in the Nutmeg, it is known as an *Arillode*.

The *Nucellus* or *Kernel* consists of tissue containing albumen, when this substance is present, and the *embryo*. Albumen is the name given the nutritive matter stored in the seed. The funiculus or seed stalk is usually absent in the official seeds. The scar left by its separation is called the *hilum*. When the funiculus is continued along the outer seed coat, it is called the *raphe*.

#### MODE OF FORMATION OF DIFFERENT TYPES OF ALBUMEN

If the egg-cell within the embryo sac segments and grows into the embryo and, stretching, fills up the cavity without food material laid down around it, it happens that the nutritive material lingers in the cells of the nucellus pressing around the embryo. This is called *Perispermic albumen*. Seen in the *Polygonaceæ*.

In by far the greater number of Angiosperms, the endosperm nucleus, after double fertilization, divides and redivides, giving rise to numerous nuclei imbedded in the protoplasm of the embryo sac, outside of the developing embryo. Gathering protoplasm about themselves and laying down cell walls they form the endosperm tissue outside of the embryo. Into this tissue food is passed constituting the *Endospermic albumen*.

In the *Marantaceæ*, *Piperaceæ*, etc., nutritive material is passed into the nucellar cells causing them to swell up, while to one side a small patch of endosperm tissue accommodates a moderate amount of nourishing substance, thus resulting in the formation of abundant *perisperm* and a small reduced *endosperm*.

*Exalbuminous seeds* are those in which the albumen is stored in the embryo during the growth of the seed. Such seeds show the fleshy embryo taking up all or nearly all the room within the seed coat. Examples: **Physostigma**, **Amygdala**, etc.

*Albuminous seeds* are those in which the nourishment is not stored in the embryo until germination takes place. Such seeds show a larger nourishing tissue region and a smaller embryo region. Examples: **Nux Vomica**, **Myristica**, **Linum**, etc.

**Gross Structure of a Monocotyl Seed** (*With fruit wall attached*), *Indian Corn*.—The ripened seed of Indian Corn is surrounded by a thin, tough pericarp which is firmly adherent to and inseparable from the *Spermoderm* or seed coat. Because of this fact, while in reality a fruit called a caryopsis or grain, this structure is sometimes erroneously termed a seed.

The mature grain of most varieties of Indian Corn is flattened and somewhat triangular in outline, the summit being broad and the base comparatively narrow. The summit is indented and often marked by a small point which represents a vestige of the style. The basal or "tip" region marks the part of the grain which was inserted into the cob. Upon it may be found papery chaff, representing parts of the pistillate spikelets. The groove noted on the broader surface indicates the position of the embryo.

**Histology of the Indian Corn Seed** (*With fruit wall attached*).—If a longitudinal section be cut through the lesser diameter of a soaked grain, the following histologic characteristics will be observed:

1. The *Pericarp* or ripened ovarian wall which, alike with all other grains, adheres firmly to the wall of the seed forming a portion of the skin of the grain. The pericarp comprises an outer epicarp of elongated cells with thin cuticle, a mesocarp of thicker walled cells without, becoming thinner within and a layer of tube cells.

2. The *Spermoderm* or seed coat, a single layer of delicate elongated cells.

3. The *Perisperm*, another layer directly underneath the *Spermoderm*, difficult to distinguish without special treatment, and representing the ripened nucellar tissue of the ovule.

4. The *Endosperm* or nourishing tissue, consisting of: (a) The Aleurone Layer, for the most part a single row of cells, containing aleurone grains. Some of the cells may be seen to be divided by tangential partitions. (b) Starch Parenchyma, consisting of two regions: an outer horny zone composed of cells containing for the most part polygonal starch grains and oil droplets; and an inner mealy zone of cells with mostly rounded starch grains.

5. The *Embryo*, consisting of a single shield-shaped cotyledon adjoining the endosperm, the plumule or rudimentary bud at the end of the caulicle or rudimentary stem and the radicle or rudimen-

tary root, with its tip covered by a root cap. Continuous with the root cap is a root sheath or *coleorhiza*. The cotyledon or seed leaf consists of two parts: the *scutellum* which lies next to the endosperm, and is an organ of absorption; and the *sheathing portion* which surrounds and protects the rest of the embryo.

The embryo contains oil and proteids, but no starch.

If a similar longitudinal section of a soaked grain be mounted in dilute iodine solution, the contents of the aleurone cells will be colored yellow indicating their proteid nature, while the starch grains will take on a blue to violet coloration. The endosperm will be observed taking up most of the room within the seed coat. The contents of its cells are not baled out to the embryo until after germination begins. Indian Corn is therefore an *albuminous seed*.

### A MONOCOTYL SEEDLING

**Germination.**—When any viable seed is planted in suitable soil, and furnished with oxygen and water and a certain degree of heat, *germination* takes place. In the presence of moisture, etc., the seed swells, the ferments present within the cells of the endosperm then change the insoluble proteid, starch, and oil to soluble materials, which, in the case of Indian Corn, are absorbed in solution by the scutellum which bales this nourishment out to other parts of the growing embryo, there to be used in part in constructing new tissues, and in part to be consumed by oxidation or respiration. The process of respiration or breathing takes place when the plant takes in oxygen and gives off carbon dioxide. The oxygen oxidizes the tissues with an accompanying release of energy, which latter is necessary to life and growth.

The combined pericarp and spermoderm bursts opposite the tip of the radicle, and the radicle, piercing through the cotyledonary sheath, protrudes. The cleft in the coat lengthens to the point opposite the tip of the plumule, which also protrudes after bursting through the cotyledonary sheath. The radicle, next, grows downward into the soil forming the primary root, and develops upon itself secondary or lateral roots, all of which give rise to root-hairs just above their root caps. Additional lateral roots emerge above the scutellar region

which ere long attain the size of the first or primary root. The caulicle, carrying upon its tip the plumule, elongates and forms the stem; the leaves of the plumule spread out and turn green to function as foliage leaves. The perforated cotyledonary sheath grows out surrounding both the root and the stem for a portion of their length. By this time all or nearly all of the nourishment stored in the endosperm has been absorbed and assimilated by the young seedling and the coat and scutellum, left behind, gradually decay and disappear. The root-hairs absorb nourishment from the soil, the green leaves build up carbohydrates, prop-roots make their appearance at the first node (joint) above ground, and the seedling grows larger.

**Gross Structure of a Dicotyl Seed, *Phaseolus lunatus* (Lima Bean).**—The Lima Bean Seed shows a flattened-ovate to somewhat reniform outline. Externally it exhibits a polished seed coat which is perforated on its basal side by a minute pore called the *micropyle* or *foramen*. Just below this pore will be noted the *hilum* or scar which represents the point of detachment from the *funiculus* or stalk which connected the seed during its growth with the wall of the fruit. Upon soaking the seed in water, it is possible to remove the *seed coat* or *spermoderm*. This done, the embryo will be exposed. The *two fleshy cotyledons* are first seen. Upon spreading these out, convex sides down, the rest of the embryo, consisting of a thin leafy structure surrounding a bud and called the *plumule*, the *caulicle* or rudimentary stem and in line with the latter, the *radicle*, or rudimentary root, will be seen.

**Histology of the Lima Bean Seed.**—In transverse sections, the following microscopic structures will be evident:

1. *Spermoderm* of three regions, viz.: Palisade cells, Column cells, and Spongy Parenchyma. The palisade cell layer is composed of vertically elongated thick-walled cells which are covered on their outer faces by a clear glistening cuticle. The cells are 60 to 80 $\mu$  long and 12 to 20 $\mu$  wide. The column cells, found forming a layer directly beneath the palisade zone, are hour-glass-shaped and 25 to 35 $\mu$  long by 14 to 35 $\mu$  wide.

The *spongy parenchyma* forms a zone of several layers of thin-walled parenchyma cells, the cells of the outer and inner layers being considerably smaller than the middle layers.



2. *Embryo*, the two cotyledons of which make up the greatest bulk. These are composed of an epidermis covering over a region of mesophyll. The mesophyll is constituted of moderately thick-walled cells which contain ellipsoidal and kidney-shaped starch grains up to  $65\mu$  in length. A conspicuous branching cleft will be seen in the larger grains.

In the Lima Bean, the nourishment is stored in the embryo during the growth of the seed. It is, therefore, *exalbuminous*.

## CHAPTER VIII

### TAXONOMY

#### DIVISION I.—THALLOPHYTA

Plants, the greater number of which, consist of a thallus, a body undifferentiated into root, stem or leaf. The group nearest to the beginning of the plant kingdom presenting forms showing rudimentary structures which are modified through division of labor, differentiation, etc., in higher groups.

#### SUBDIVISION I.—PROTOPHYTA (SCHIZOPHYTA)

A large assemblage of "fission plants" comprising the bacteria and blue-green algæ. In the simplest types no nucleus is present, but as we arise in scale through the bacteria and blue-green algæ, there is to be observed an open granular, gradually growing to a crescentic, chromatin mass that may be called a nucleus. A common method of asexual reproduction is possessed by these plants whereby the cell cleaves or splits into two parts, each of which then becomes a separate and independent organism.

#### I. SCHIZOMYCETES—BACTERIA

Bacteria are minute, unicellular, colorless, rarely weakly red or green colored, non-nucleate vegetable organisms destitute of chlorophyll. They serve as agents of decay and fermentation and are frequently employed in industrial processes. According to the various phenomena they produce, they may be classified as follows: (*a*) Zymogens producing fermentation; (*b*) Aerogens producing gas; (*c*) Photogens producing light; (*d*) Chromogens producing color; (*e*) Saprogens, producing putrefaction; (*f*) Pathogens, producing disease.

**Physical Appearance of Bacterial Colonies and Individual Forms.** Because of their minute size—a space the size of a pinhead may

hold eight billion of them—the student commences his study of bacterial growths in colonies or cultures, each kind possessing characteristics by which they may be distinguished and differentiated.

The individuals in the colony, depending upon the kind of bacteria under examination, may be globular, rod-shaped, or spiral. Bacteria are classed according to form into the following families and genera.



FIG. 70.—Types of micrococci. (After Williams.)

**Family I.—Coccaceæ.**—Cells in their free condition globular, becoming but slightly elongated before division. Cell-division in one, two or three directions of space.

**A. Cells without Flagella.**

1. Division only in one direction of space forming an aggregation resembling a chain of beads—*Streptococcus*.
2. Division in two directions of space forming an aggregation resembling a cluster of grapes—*Staphylococcus*.
3. Division in three directions of space forming a package-shaped or cubical aggregation—*Sarcina*.

**B. Cells with Flagella.**

1. Division in two directions of space—*Planococcus*.
2. Division in three directions of space—*Planosarcina*.



FIG. 71.—Types of bacilli. (After Williams.)

**Family II.—Bacteriaceæ.**—Cells longer than broad, generally two to six times, straight or only with an angular bend, never curved or

spiral, division only at right angles to axis or rod; with or without flagella and endospores.

1. Flagella and endospores absent—Bacterium.
2. Flagella and endospores present—Bacillus.

**Family III.—Spirillaceæ.**—Cells curved or spirally bent, generally motile through polar flagella.

1. Cells stiff, not flexile.
  - (a) Cells without flagella—Spirosoma.
  - (b) Cells with one, very rarely with two polar flagella—Microspira.
  - (c) Cells with a bundle of polar flagella—Spirillum.
2. Cells flexile, spiral very close—Spirochæta.

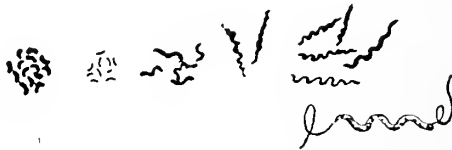


FIG. 72.—Types of spirilla. (After Williams.)

**Family IV.—Mycobacteriaceæ.**—Cells short or long cylindrical or clavate-cuneate in form, without a sheath surrounding the chains of individuals, without endospores, with true dichotomous branching.

A. In cultures possessing the characters of true bacteria. Growth on solid media smooth, flat, spreading. Rods with swollen ends, or cuneate or clavate forms—Corynebacterium.

B. Cultures on solid media raised, folded or warty. Generally short slender rods, rarely short branched. Take the tubercle stain—Mycobacterium.

**Family V.—Chlamydobacteriaceæ.**—Thread-like, composed of individual cells, surrounded by a sheath. Simple or with true branching. Ordinary vegetative growth by division in only one direction of space, *i.e.*, at right angles to the longer axis.

- A. Cell contents without sulphur granules.
  1. Filaments unbranched.
    - (a) Cell-division only in one direction of space.

(b) Cell-division in gonidial formation in three directions of space—*Streptothrix*.

\*Marine forms with cells surrounded by a very delicate hardly discernible sheath—*Phragmidiothrix*.

\*\*Fresh-water forms with easily discernible sheath—*Crenothrix*.

2. Filaments branched.

B. Cell contents with sulphur granules—*Thiothrix*.

**Family VI.—*Beggiatoaceæ*.**—Thread-like, without a capsule, but with an undulating membrane. Cell contents show sulphur granules.

A. Threads apparently not septated, septa only faintly visible with iodine staining. Colorless or faintly rose-colored—*Beggiatoa*.

**Sporulation.**—A large number of bacteria possess the power of developing into a resting stage by a process known as sporulation or spore formation. Sporulation is regarded as a method of resisting unfavorable environment. This is illustrated by the anthrax bacilli which are readily killed in twenty minutes by a 10 per cent. solution of carbolic acid, and able, when in the spore condition, to resist the same disinfectant for a long period in a concentration of 50 per cent. And, while the vegetative forms show little more resistance against moist heat than the vegetative form of other bacteria, the spores will withstand the action of live steam for as long as ten to twelve minutes or more.

Whenever the spores are brought into favorable condition for bacterial growth, as to temperature, moisture and nutrition, they return to the vegetative form and then are capable of multiplication by fission in the ordinary way.

**Reproduction.**—Bacteria multiply and reproduce themselves by cleavage or fission. A young individual increases in size up to the limits of the adult form, when by simple cleavage at right angles to the long axis, the cell divides into two individuals.

**Morphology Due to Cleavage.**—According to limitations imposed by cleavage directors, the cocci assume a chain appearance, or a grape-like appearance, or an arrangement in packets or cubes having three diameters. This gives rise to the

*Staphylococcus* (plural, *staphylococci*), from a Greek word referring to the shape of a bunch of grapes.

*Streptococcus* (plural, *streptococci*), from a Greek word meaning chain-shaped.

*Sarcina*, package-shaped or cubical.

**Form of Cell Groups after Cleavage.**—The individual bacteria after cleavage may separate, or cohere. The amount of cohesion, together with the plane of cleavage, determines the various forms of the cell groups. Thus, among the cocci, diplo- or double forms may result giving rise to distinguishing morphological characteristics. Similarly among the bacilli characteristic forms result as single individuals and others which form chains of various lengths.

**Rapidity of Growth and Multiplication.**—The rapidity with which bacteria grow and multiply is dependent upon species and environment. The rapidity of the growth is surprising. Under favorable conditions they may elongate and divide every twenty or thirty minutes. If they should continue to reproduce at this rate for twenty-four hours a single individual would have 17 million descendants. If each of these should continue to grow at the same rate, each would have in twenty-four hours more, 17 million offspring, and then the numbers would develop beyond conception. However, such multiplication is not possible under natural or even artificial conditions, both on account of lack of nutritive material and because of the inhibition of the growth of the bacteria by their own products. If they did multiply at this rate in a few days there would be no room in the world but bacteria.

**Chemical Composition of Bacteria.**—The quantitative chemical composition of bacteria is subject to wide variations, dependent upon the nutritive materials furnished them. About 80 to 85 per cent. of the bacterial body is water; proteid substances constitute about 50 to 80 per cent. of the dry residue. When these are extracted, there remain fats, in some cases wax, in some bacteria traces of cellulose appear, and the remainder consists of 1 to 2 per cent. ash.

The proteids consist partly of nucleo-proteids, globulins, and protein substances differing materially from ordinary proteids. Toxic substances known as endotoxins to distinguish them from bacterial poisons secreted by certain bacteria during the process of growth, also occur.

SOME BACTERIA PRODUCING DISEASES IN MAN OR THE  
LOWER ANIMALS

<i>Organism</i>	<i>Disease</i>
Staphylococcus pyogenes aureus.....	Boils, abscesses, carbuncles
Streptococcus erysipelatis.....	Erysipelas
Micrococcus meningitidis.....	Cerebrospinal meningitis
Micrococcus gonorrhœæ.....	Gonorrhœa
Micrococcus melitensis.....	Malta fever
Micrococcus catarrhalis.....	Catarrh
Bacillus anthracis.....	Anthrax
Bacterium diphtheriæ.....	Diphtheria
Bacillus typhosus.....	Typhoid fever
Bacterium influenzæ.....	Influenza
Bacillus tetani.....	Tetanus
Bacillus lepræ.....	Leprosy
Bacillus chauvei.....	"Blackleg" of cattle
Bacillus aërogenes capsulatus.....	Emphysematous gangrene
Bacterium tuberculosis.....	Tuberculosis
Bacterium mallei.....	Glanders
Streptococcus pneumoniaë (Diplococcus pneumoniaë)	Pneumonia (croupous or fibrinous pneumonia)
Spirillum choleraë asiaticæ.....	Cholera
Spirillum obermeieri.....	Relapsing fever
Streptothrix (Actinomyces) bovis.....	Actinomycosis in cattle
<i>Some Bacteria Producing Diseases in Plants</i>	
Actinomyces Myricarum.....	Tubercles upon and lesions within Myrica and Comp-tonia
Bacterium tumefaciens.....	Crown gall
Bacterium savastanoi.....	Olive knot
Bacillus amylovorus.....	Pear blight
Pseudomonas juglandis.....	Walnut blight
Bacillus Solanacearum.....	Wilt of Solanaceæ
Bacillus tracheiphilus.....	Wilt of Cucurbits
Pseudomonas Stewarti.....	Wilt of Sweet Corn

**Mounting and Staining of Bacteria.**—The mounting and staining of bacteria may be accomplished as follows:

1. Take the square or round cover slip, which has been previously cleaned, out of the alcohol pot. Dry it between filter paper.
2. Hold it in the bacteriologic forceps, which is so constructed that a spring holds the cover slip firmly while an enlargement of the wire

handle permits the placing of the forceps on the table while the culture material is obtained.

3. Place several drops of distilled water on the cover slip and add a loop full of the organism secured from the pure culture in a test tube as follows:

4. Remove the cotton plug by the third and fourth fingers of the left hand.

5. Hold the open test tube between the thumb and forefinger of the left hand.

6. By means of a previously flamed platinum needle, remove a little of the culture from the surface of the culture media.

7. Replace the cotton plug.

8. Add the culture media to the drop of distilled water on the cover slip and distribute this material by stirring.

9. Evaporate the water on the cover slip to dryness by holding it some distance above the Bunsen flame and slowly enough to prevent connection circles being formed by the material affixed to the cover.

10. Pass the cover glass three times through the Bunsen flame.

11. Apply the stain, which should remain long enough to stain the objects.

12. Wash off the stain with distilled water.

13. Dry the cover glass above the flame.

14. Apply a drop of balsam, turn the cover slip over and drop it on to the center of a glass slide previously provided and cleaned for this purpose.

**Gram's Method.**—This is a method of differential bleaching after a stain. The cover glass preparations or sections are passed from absolute alcohol into Ehrlich's anilin gentian violet, where they remain one to three minutes, except tubercle bacilli preparations which remain commonly twelve to twenty-four hours. They are then placed for one to three minutes (occasionally five minutes) in iodine potassium iodide water (iodine crystals 1, potass. iodide 2, water 300), with or without washing lightly in alcohol. In this they remain one to three minutes. They are then placed in absolute alcohol until sufficiently bleached, after which they are cleared in clove oil and mounted in balsam.

Certain organisms, when stained by this method give up the stain



and are called "Gram negative;" others retain the color and are called "Gram positive." Examples of the latter are *B. diphtheriæ*, *Bacillus anthracis*, and *Bacillus tetani*.

**Stains.**—One of the most useful bacteriologic stains is *Ziehl's Carbol Fuchsin*, prepared as follows:

Fuchsin (basic), 1.

Absolute Alcohol, 1.

Carbolic Acid (5 per cent. aqueous solution), 100.

The fuchsin should be dissolved first in the alcohol and then the two fluids mixed.

**Ehrlich's Anilin Water Gentian Violet.**—Anilin Oil Water, 75 parts.

Sat. Sol. Gentian Violet in Alcohol, 25 parts.

Anilin oil water is made by adding 2 mls anilin to 98 mls distilled water; shake violently. Filter through filter paper several times.

**Löffler's Methylene-blue.**—

Sat. sol. Methylene-blue in Alcohol..... 30 mls

Sol. KOH in distilled water (1:10,000).....100 mls

Mix the solutions.

**Stain for "Acid Proof" Bacteria Including *B. Tuberculosis*.**—

1. Flood the cover glass with *Ziehl's carbol fuchsin* and boil over the flame for thirty seconds.

2. Wash and decolorize with a 2 per cent. solution of HCl in 80 to 95 per cent. alcohol until the thinner portions of the film show no red color.

3. Wash in water.

4. Counter stain for contrast with *Löffler's Methylene-blue*.

5. Wash and examine.

**Van Ermengem's Flagella Stain.**—1. Mordant:

Osmic acid (2 per cent. aqueous solution)..... 50

Tannin (10 to 25 per cent. in water)..... 100

Four drops of glacial acetic acid may be added to this.

2. Silver Bath:

Dissolve 0.25 to 0.5 per cent. nitrate of silver in distilled water in a clean bottle.

## 3. Reducing and Strengthening Bath:

Gallic acid.....	5
Tannin.....	3
Fused sodium acetate.....	10
Distilled water.....	350

The flamed cover glass is first covered with the mordant for one-half hour, or if in a thermostat at 50°C. for five to ten minutes. The mordant is then carefully removed by thorough washing in water, alcohol and water. The cover (film side up) is now put into the silver bath (a few mils in a clean beaker or watch glass) for a few seconds, during which time it is gently agitated. Without rinsing it is next put into a few mils of the reducing solution and gently agitated until the fluid begins to blacken. It is then washed in water and examined. If not stained deeply enough the cover is returned to the silver bath. It is finally dried and mounted in balsam. All the dishes must be scrupulously clean. The fluids must not be contaminated by the fingers nor by dipping iron or steel instruments into them.

## 2. CYANOPHYCEÆ

Plants which are sometimes termed *blue-green algæ*. They contain chlorophyll, a green pigment and phycocyanin, a blue pigment, a combination giving a blue-green aspect to the plants of this group. Found everywhere in fresh and salt water and also on damp logs, rocks, bark of trees, stone walls, etc. Examples: *Oscillatoria*, *Glæocapsa*, and *Nostoc*.

**Glæocapsa.**—This blue-green alga is commonly found on old, damp flower pots in greenhouses and on damp rocks and walls near springs, where it forms slimy masses. Under the microscope a mount of *Glæocapsa* will be seen to consist of isolated protoplasts and groups of protoplasts, surrounded by concentric gelatinous envelopes. Each protoplast consists of a protoplasmic mass which contains blue and green pigments. No definitely organized nucleus is apparent but chromatin in the form of granules is scattered through the protoplasm. The whole is surrounded by a

cell wall which undergoes mucilaginous modification producing thus the soft gelatinous envelopes which encircle parent-, daughter-, grand-daughter- and even great-granddaughter-cells.

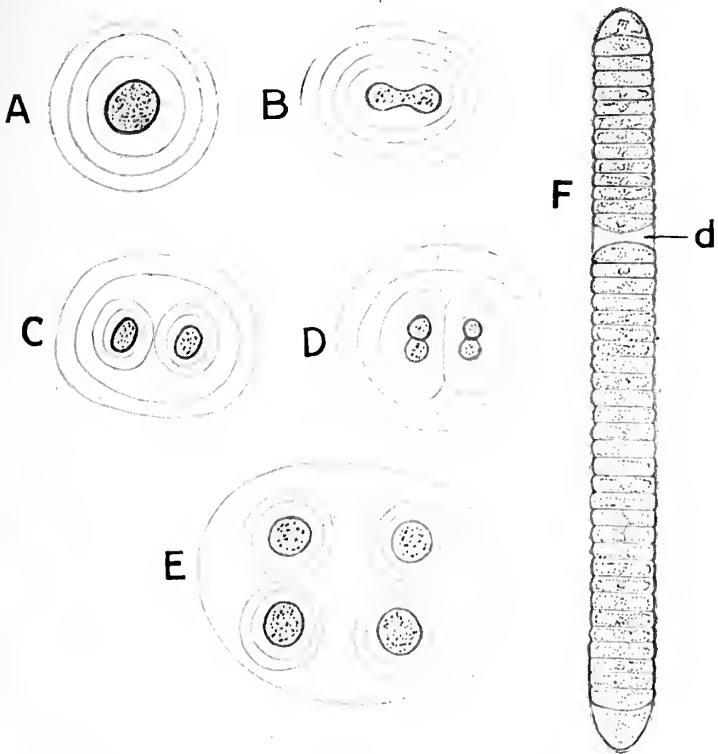


FIG. 73.—A, B, C, D, E, *Gloeocapsa*; F, *Oscillatoria* showing a dead cell (*d*) which marks a place of separation into segments. (A), *Gloeocapsa*, parent cell composed of central protoplast containing scattered chromatin granules, surrounded by cell wall and 3 mucilaginous envelopes; (B), parent cell is shown elongated, the protoplast in process of division to form two daughter protoplasts; (C), daughter protoplasts, each surrounded by two gelatinous envelopes and both within the original parent envelopes; (D) the daughter protoplasts shown in C have just divided to form granddaughter protoplasts which have later separated, each forming envelopes of its own but all four encircled by the parent envelope.

**Oscillatoria.**—*Oscillatoria* is a blue-green filamentous organism found abundantly on the surface of the mud of drains and ditches as well as in ponds where the water is foul. The filament is slender

and composed of compactly arranged disc-shaped cells which are all alike, excepting the terminal ones which appear rounded off. The filaments tend to be agglomerated in thick felts or gelatinous



FIG. 74.—*Nostoc*. (h), a heterocyst.

masses and each possesses peculiar oscillating and forward movements. At the time of reproduction the filament breaks up transversely into short segments, each of which, by fission occurring among its cells, grows into a new filament.

**Nostoc.**—*Nostoc* occurs on the damp ground bordering streams or in slow bodies of water as greenish or brownish tough gelatinous masses varying in size from a pea to a hen's egg. When one of these masses is dissected and examined microscopically, it is seen to contain, imbedded in a gelatinous matrix, numerous serpentine filaments, composed of spherical or elliptical cells loosely attached to each other in chain-like fashion. Most of the cells are of the blue-green vegetative kind but there occur at intervals larger cells, often devoid of protoplasm which are termed *heterocysts*. Frequently the filaments break apart on either side of the heterocyst, setting free segments of cells which grow into new filaments.

#### SUBDIVISION II.—MYXOMYCETES, OR SLIME MOLDS

Terrestrial or aquatic organisms, frequently classified as belonging to the animal kingdom and found commonly on decaying wood, leaves, or humous soil in forests. Their vegetative body consists of a naked, multinucleated mass of protoplasm called the *plasmodium*, which has a creeping and rolling amœboid motion, putting out and retracting regions

of its body called *pseudopodia*. The size of the plasmodium varies from a ten-cent piece to several square feet of surface. It is net-like, the net being of irregular dimensions. Like the amœba the outer portion of the plasmodium is clear and watery and known as the *ectoplasm*, the inner portion is granular and called the *endoplasm*. Like the amœba and unlike other plants, this slimy body engulfs solid food by means of its pseudopodia instead of admitting it in solution. It is extremely sensitive to light being negatively heliotropic, *i.e.*, turning away from the sun's rays.

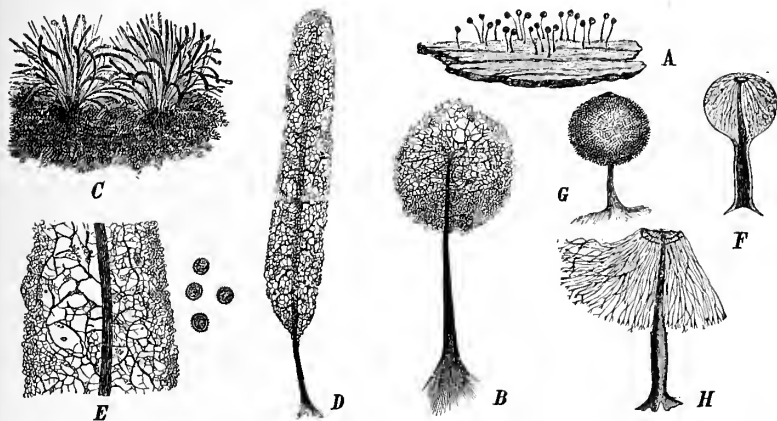


FIG. 75.—A, B, *Comatricha nigra*. A, Sporangium, natural size; B, capillitium, 20/1; C, E, *Stemonitis fusca*; C, sporangium, natural size; D and E, capillitia, 5/1, 20/1; F, H, *Enerthema papillatum*, F, unripe; G, mature sporangium, 10/1; H, capillitium, 20/1. (C, D, after nature. A, F, G, H, after Rostafinski; B, E, after de Bary in *Die natürlichen Pflanzenfamilien* I. 1, p. 26.)

At the time of reproduction, the plasmodium creeps to the surface. The whole plasmodium then forms one or more fructifications. These fructifications vary from cushion-like masses (*athallia*) to more elevated bodies in which the net-like structure of the plasmodium is preserved (*plasmodiocarps*) to stalked *sporangia* (spore cases). All of the fructifications, however, produce *spores*. During wet weather amœboid protoplasts (*swarm spores*) escape from the spores, each developing a single *cilium* and moving actively about. In time the cilia disappear and these swarm spores coalesce in smaller than larger groups to form a plasmodium.

## SUBDIVISION III.—ALGÆ

Low forms of thallophytes of terrestrial and aquatic distribution consisting for the most part of single cells or rows of single cells joined end to end to form filaments. The higher forms, however, possess structures, which might be compared to stems and leaves of higher plants although more rudimentary in structure. They contain chlorophyll or some other pigment, and so can use the  $\text{CO}_2$  and  $\text{H}_2\text{O}$  in the same manner as higher plants, *e.g.*, in assimilating and providing for their own nutrition. Archegonia are absent in this group.

## CLASS I.—CHLOROPHYCÆ, THE GREEN ALGÆ

A large assemblage of terrestrial or aquatic plants many of which are vastly different from one another. In this group the cells are observed to possess distinct nuclei and chromatophores, the latter containing a green oil-like pigment called chlorophyll. Reproduction is mostly by ciliated cells called *zoöspores* but in some forms is accomplished by the fertilization of egg-cells and in others by simple division.

1. **Order Protococcales or One-celled Green Algæ.**—This order contains nearly all of the one-celled green algæ excepting the diatoms and desmids.

**Family Pleurococcaceæ.**—*Pleurococcus vulgaris* is a one-celled green alga, millions of which, living together in colonial fashion, constitute the so-called "green stain" that is common on the north sides of tree trunks, stone walls and fences. Each organism consists of a protoplast surrounded by a cell wall of cellulose. The protoplast contains a chromatophore, cytoplasm and nucleus. Reproduction takes place by the protoplast dividing into two equal parts and laying down a cell wall forming two daughter-protoplasts. These may again divide to form four granddaughter-protoplasts. Still another division may occur as a result of which eight great-granddaughter-protoplasts are formed which frequently adhere to one another forming colonies.

2. **Order Confervales.**—In this order are included a variety of green filamentous and membranous forms some of which show sexual reproduction.

**Family Ulothricaceæ.**—*Ulothrix zonata*, a typical representative of this family, is a filamentous organism found growing on stones around ponds, on rocks along the shores of lakes, in slow-moving streams, etc. Each filament is unbranched and consists of a row of short cells, one of the terminal cells, called the rhizoid cell, being elongated and serving as an attachment structure. Each cell consists of a cell wall of cellulose enclosing cytoplasm, a nucleus and a wide band-shaped green chromatophore, more or less cylindrical in shape. The chromatophore lies next to the cell wall and contains *pyrenoids* or starch-forming centers. The filament grows in length by the fission of its various component cells. After attaining a

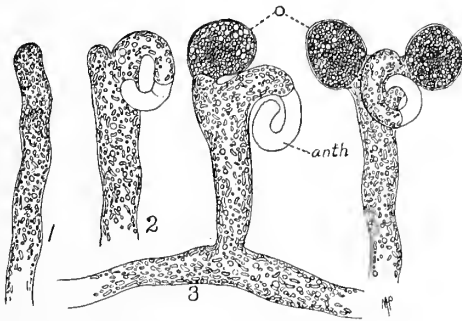


FIG. 76.—*Vaucheria terrestris*. anth, antheridium (empty); o, oögonia. (Gager.)

certain size it reproduces either asexually or sexually. Asexual reproduction takes place by certain cells becoming altered in their protoplasmic contents through division to form rounded or pear-shaped *zoöspores*. Each zoöspore contains a red pigment spot and bears four cilia (protoplasmic outgrowths). The zoöspores escape into the water by lateral openings in the walls of cells containing them. They swim rapidly about, propelled by their cilia, and ere long attach themselves to various objects and grow into *Ulothrix* filaments. The sexual method of reproduction is effected through the production of many *gametes*, in cells of the filament, which resemble the zoöspores in shape but differ from them in being smaller and possessing but two cilia. These escape into the water, and, after swimming about for a short time, come together in pairs and

fuse with one another. The product of the fusion of each pair of these like gametes is termed a *zygospore*. The zygospore swims about but finally comes to rest, remaining quiescent for a considerable length of time. It then enlarges and its protoplasmic content divides to form several zoöspores which, escaping from the cell, swim about for a while and finally, attaching themselves to objects, grow into filamentous *Ulothrix* organisms.

3. **Order Conjugales.**—To this order belong the desmids and pond scums which are distinguished from other green algæ by presenting no motile stages in their life histories. They are all of fresh-water habit and reproduce by conjugation.

**Family Desmidaceæ.**—The desmid family includes a number of genera of unicellular as well as filamentous green plants that present a variety of shapes. Each unicellular desmid is characterized by being composed of two like halves frequently separated by each other by a constriction called the *isthmus*. In each half there is a *chromatophore* containing *pyrenoids*. The *nucleus* is found in the isthmus. Reproduction is accomplished either asexually by fission or sexually by conjugation.

**Family Zygnemaceæ.**—This is a family of pond scums including the well-known genera, *Spirogyra* and *Zygnema*.

*Spirogyra* or *Brooksilk* is a filamentous organism found suspended or floating in masses in quiet water. Each filament when examined microscopically will be found to consist of more or less elongated cylindrical cells arranged end to end, the terminal cells having rounded extremities. Each cell has a cell wall of cellulose within which is to be found a thin film of *ectoplasm*. One or more spirally shaped *chromatophores* will be seen directly within this area. Each chromatophore contains *chlorophyll* and a number of *pyrenoids*. In the center of the cell the *nucleus* is found. Fine strands of protoplasm hold it in place and run out to the ectoplasm.

Under favorable circumstances the cells of *Spirogyra* increase rather rapidly in length. Abnormally long cells are not seen, however, because the elongating cells speedily divide, forming two daughter-cells. Under the best of conditions, division may occur every night. In this way the filaments are rapidly made longer. Sooner or later they break and in this way the plant multiplies.



*Spirogyra* has also a process of sexual reproduction known as conjugation. This process occurs normally from March to June and July, but can be induced in the laboratory by allowing the water

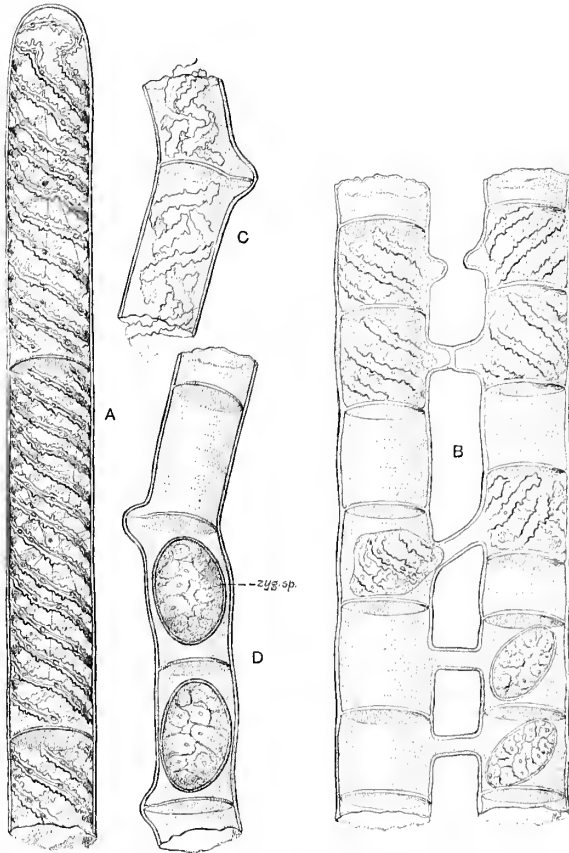


FIG. 77.—*Spirogyra* sp. A, terminal portion of vegetative filament; B, stages of scalariform conjugation; C, preparation for lateral conjugation; D, zygospores formed by lateral conjugation. (Gager.)

in the vessel in which it is growing to slowly evaporate. Two filaments arrange themselves side by side, and the cells lying opposite each other undergo internal changes so as to form *gametes* or sexual

cells. Each protrudes a process or *conjugation tube*; these unite and the protoplasm from one cell passes over and coalesces with that in the cell opposite. The result of the process is a new cell called a *zygospore* or *zygote*. This is set free by decay of the walls of the old cell and falls to the bottom of the water, there to undergo a resting stage until favorable conditions for growth arise.

4. **Order Diatomales.**—**Family Diatomaceæ.**—This family comprises several thousand species of unicellular plants called *Diatoms* which are found in fresh, brackish and salt water forming much of the diet of small animals. While unicellular they frequently are united in colonies. They all possess chromatophores containing chlorophyll but this green pigment is often obscured by the presence also of a brown pigment.

The most striking peculiarity of the group is the structure of the enclosing cell wall. This is in the form of a siliceous case consisting of two *valves* which fit into each other like the halves of a pill box. The valves, which are beautifully sculptured, are similar except that one is slightly larger than the other so as to fit over it. Diatoms vary in form being either circular, linear, elliptical, cylindrical rhomboidal, triangular or fan-shaped, etc. Some are borne on the ends of stalks, while others are held in gelatinous masses. Their siliceous skeleta are deposited constantly on the floor of ponds, rivers, lakes and seas, often in such abundance as to form Diatomaceous earths or Kieselguhrs (Siliceous Earths). Huge geological deposits of this material have been found in various parts of the world. The most remarkable for extent as well as for the number and beauty of the species contained in it is that at Richmond, Virginia. It is in many places 25 to 40 feet in depth and extends for many miles. Many of the diatomaceous earths are useful as absorbent and polishing powders. The United States Pharmacopœia IX recognizes, under the name of Terra Silicea Purificata (Purified Siliceous Earth), a powder consisting of the frustules and fragments of diatoms which has been purified by boiling with diluted hydrochloric acid, washed and calcined.

*Diatoms* exhibit two modes of reproduction, viz., fission and formation of an *auxospore*. The more common method is that of fission but this is peculiar for these plants. The cell-contents within

the siliceous case separate into two distinct masses and the valves separate slightly from each other. As the two daughter-masses become more and more developed, the valves of the parent-cell are pushed more widely apart. Each of the two masses secretes for itself a new valve on the side opposite to the original valve. When the process is completed the girdle of the parent-diatom separates and the two daughter-diatoms thus become independent plants. Each of these possesses one of the parent valves and a second, which it has formed itself more or less parallel to the first.

In a number of species, repeated fission results in the formation of succeeding smaller and weaker individuals. This process, however, goes on only for a certain number of generations until the decrease of size has reached a limit for the species, when the plant is rejuvenated by the formation of an *auxospore*. This may be formed with or without the conjugation of two parent-protoplasts. In either case the auxospore resulting undergoes a resting stage after which it develops new valves. The newly formed diatom is then several times the size of the individual or individuals which contributed to its formation and is endowed with renewed vigor for growth and division.

5. **Order Siphonales** (*Siphon Algæ*).—This group is characterized by the peculiarity that the organisms constituting it possess protoplasm containing myriads of nuclei within a common filament or cell cavity not segmented by cell walls. The term *cænocyte* has been given to such structures which consist of a many-nucleated mass of protoplasm surrounded by a cell wall. Some of the siphon algæ reproduce by zoöspore formation, others by conjugation as well as zoöspore formation while *Vancheria*, the green felt, stands out alone in reproducing both by the formation of a single zoöspore and by the production also of *oögonia* and *antheridia* with resultant fertilization.

6. **Order Charales** (*The Stoneworts*).—**Family Characeæ**.—The highest group of algæ, possessing forms which are differentiated into stems, leaves and rhizoids.

*Chara*, a type of this family, is a submerged fresh-water plant which fastens itself to the muddy bottom of ponds, ditches and slow streams by means of slender filaments called rhizoids. From these

there arises a many noded (jointed) stem which bears whorls of slender green leaves at its nodes. Branches are also found issuing from some of the nodes which duplicate in appearance the main stem. Reproduction is either asexual or sexual. Asexual reproduction is accomplished by means of tuber-like bodies borne on submerged parts or by special branches which form *rhizoids* on their lower nodes and later become separated from the parent plant. Sexual reproduction is effected through the formation of *oögonia* (female sex organs) and *antheridia* (male sex organs). These in some species are borne on the same plant; in others, on different plants. In all cases the sexual organs are produced at the nodes. The oögonium develops within itself a large *ovum* or egg. The antheridium produces within its wall numerous motile sperms. Upon the maturation of the antheridium the sperms are liberated into the water, and, propelled by their cilia, find their way to the oögonia which they enter, the one best adapted fusing with the egg in each case and fertilizing it. The resultant cell is called the *oöspore*. This undergoes a resting stage and later germinates as a *proembryo*. The proembryo consists of a simple filament and a long rhizoidal cell. From this proembryo, the adult stem arises as a side branch.

#### CLASS II.—PHAEOPHYCEÆ, THE BROWN ALGÆ

Mostly marine forms showing great diversity in the form of their vegetative bodies. They occur for the most part in salt water between the high and low tide marks. Their bodies are usually fixed to some support in the water by means of a holdfast, and are often highly differentiated both as to form and tissues. Some reach hundreds of feet in length as, for example, *Macrocystis* which grows in the Pacific Ocean off the coast of California. They all contain the brown pigment called *phycophæin* and the green pigment, *chlorophyll* both of which are present in their chromatophores. A yellowish pigment called *phycoxanthin* has also been isolated from some of the species. Many of the kelps and rockweeds belonging to this class have long been sources of iodine, potash and sodium.

**A Filamentous Brown Alga, *Ectocarpus Siliculosus*.**—*Ectocarpus* occurs as tufts of branching filaments, each of which

is many-celled. These tufts are found on eelgrass or other algae as well as attached to pilings of wharves in salt water. It is a striking illustration of the simplest form of brown algae and serves to show the beginning of a more complex form of reproduction than that observed in the forms studied up to this time. On examination of a filament we find it to consist of many cells joined end to end. A single cell has a cell wall of cellulose. Just within the cell wall there is a layer of protoplasm. Going toward the center we find an irregular chromatophore containing a brown pigment called phyco-phæin. From certain cells of the filament spherical *sporangia* (spore cases) arise, which are unicellular. They contain numerous biciliate *zoöspores*, which escape into the sea water, move about and later develop into new *Ectocarpus* plants. Along the filaments several branches will be seen. Some of these have undergone division into several cells and these again into still smaller cells until many-celled chambers have resulted, which are called *plurilocular sporangia*. Each cell of a plurilocular sporangium contains a *gamete* or sexual cell, which resembles in many details a zoöspore. When the sporangium matures these gametes are discharged into the salt water. They fuse together in pairs and form *zygospores*. Each zygospore under-

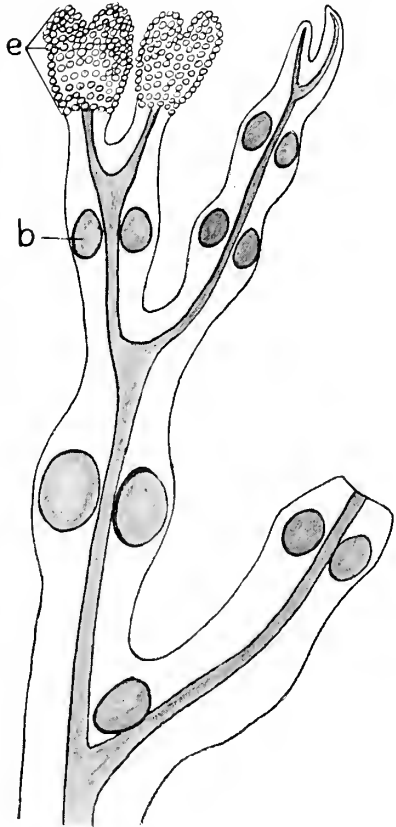


FIG. 78.—End of large branch of *Fucus vesiculosus* (natural size); *e*, receptacle; *b*, air bladder.

or sexual cell, which resembles in many details a zoöspore. When the sporangium matures these gametes are discharged into the salt water. They fuse together in pairs and form *zygospores*. Each zygospore under-

goes a resting stage and upon the advent of favorable conditions develops into a new *Ectocarpus* filament.

**Fucus Vesiculosus (The Bladder Wrack).**—This form, a brown alga, occurs as a flat thallus, which forks repeatedly, a type of branching called dichotomous. It grows near the surface of sea water, attached to rocks by means of a basal *disc-shaped holdfast*. In the upper branches of the thallus are to be found *air bladders* which are more or less spherical and usually in pairs. The tips of old branches become swollen and are termed *receptacles*. They are dotted over with minute cavities called *conceptacles*. Within these conceptacles the *antheridia*, or male sexual organs, and the *archegonia*, or female sexual organs, are produced. The conceptacles also contain numerous branching filaments called *paraphyses*, which arise from the cells lining the cavities. The antheridia are found as outgrowths of these paraphyses and produce *sperms* or male sexual cells. The *oögonium* is a large, globular, stalked cell and produces eight *eggs*, each of which is a female sexual cell. The eggs and sperm escape into the sea water. The eggs float and are surrounded by myriads of sperms. One sperm, only, gains an entrance, after which its nucleus fuses with that of the egg to form an oöspore. The oöspore, at once develops into a new *Fucus* plant.

### CLASS III.—RHODOPHYCEÆ, THE RED ALGÆ

A greatly diversified group comprising the majority of marine algæ but represented also by some fresh-water forms. The marine red algæ are generally found at or just beyond the low water mark. Their vegetative bodies vary from simple branching filaments through all gradations to forms differentiated into branching stems, holdfasts and leaves. It has been observed that many of the higher types are composed of numerous filaments which are arranged so closely and connected so intimately by protoplasmic processes as to resemble the tissues of plants higher up. Their color may be red, purple, violet, or reddish-brown or even green and is due to the presence of phycoerythrin, a red pigment, which is found in the chromatophores with but frequently masking the chlorophyll.

*Chondrus crispus* and *Gigartina mamillosa* yield the official drug

**Chondrus**, Irish Moss or Carragheen. Both are purplish-red in color. Each consists of a dichotomously branched thallus the lower portion of which is differentiated as a stipe or stalk; the basal portion of which, called the holdfast, clings to the rock. The upper part is several times forked and its terminal segments appear notched or bilobed. Scattered here and there over the segments of the thallus will be noted sporangia which, when mature, contain *tetraspores*. In *Chondrus crispus* the sporangia are elliptical and embedded in the thallus near its surface, whereas in *Gigartina* they are ovate and project outward from the surface of the segments. Upon the ripening of these structures the spores are discharged into the sea water. These sooner or later germinate into new *Chondrus* or *Gigartina* organisms. The dried mucilaginous substance extracted from *Gracilaria lichenoides*, *Gelidium* and *Gloiopeltis* and other species of red algæ growing in the sea along the eastern coast of Asia constitutes the drug **Agar**, a most valuable ingredient in culture media as well as a laxative.

*Rhodymenia palmata* or Irish Dulse is a purplish-red, flat, membranous, palmately cleft or dichotomous red alga growing on the tissues of other algæ along northern shores of the Atlantic between the low- and high-tide marks.

#### SUBDIVISION IV.—FUNGI

This great assemblage of thallophytes is characterized by the total absence of chlorophyll and so its members possess no independent power of manufacturing food materials such as starches, sugars, etc., from  $\text{CO}_2$  and  $\text{H}_2\text{O}$ . Consequently they are either *parasites*, depending for their nourishment upon other living plants or animals, called *hosts*; or *saprophytes*, depending upon decaying animal or vegetable matter in solution. Some forms are able to live either as saprophytes or parasites while others are restricted to either the parasitic or saprophytic habit. The vegetative body of a fungus is known as a mycelium. It consists of interlacing and branching filaments called *hyphæ*, which ramify through decaying matter or invade the tissues of living organisms and derive nourishment therefrom. In the case of parasites, the absorbing connections which are more or less

specialized and definite are called *haustoria*. In the higher forms the hyphæ become consolidated into false tissues, and assume definite shapes according to the species. Of this character are the fructifying organs which constitute the above ground parts of Puff Balls, Cup Fungi, Mushrooms, etc. There are four classes of Fungi, viz.: Phycomycetes, Ascomycetes, Basidiomycetes and Fungi Imperfecti.

### CLASS I.—PHYCOMYCETES, OR ALGA-LIKE FUNGI

The Phycomycetes represent a small group of fungi showing close affinity with the green algæ. Their mycelium is composed of cœnocyctic hyphæ, which suggests a close relation with the Siphonales group of green algæ. Their sexual organs are likewise similar in structure. Transverse septa appear upon the formation of reproductive organs separating these structures from the vegetative hyphæ.

#### SUB-CLASS A.—ZYGOMYCETES

(Sexual apparatus shows isogamy)

**Order 1.—Mucorales**, the black molds, mostly saprophytic. Examples: *Mucor Mucedo*, *Rhizopus nigricans*, *Thamnidium*, *Pilobolus*.

*Rhizopus nigricans* (*Mucor stolonifer*), commonly known as "Black Mold" or "Black Bread Mold," is frequently found on bread, jellies, syrups, acetic pharmaceutical extracts and other substrata, where it forms a dense thready *mycelium* bearing numerous black tiny spore cases. The source of this mold is the spores which are found in the air or water with which the attacked substratum is in contact. Each of these upon germinating sprouts out and forms three kinds of hyphæ, viz.: *rhizoidal* or *submerged hyphæ*, *sporangiohores* or *aerial hyphæ* and *stoloniferous hyphæ*. The branching rhizoidal hyphæ penetrate the substratum and secrete a diastatic ferment which changes the water insoluble carbohydrate materials into a soluble sugar which passes into solution and is absorbed by their walls. This, upon entering the hyphæ, is converted into protoplasm, and so the mold increases in size. Sporangiohores or aerial hyphæ arise vertically or obliquely from a bulged-out



common base of the rhizoidal hyphæ. Each of these when mature bears upon its summit a spheroidal *sporangium* containing numerous small brownish multinucleate spores called *endospores*. The wall

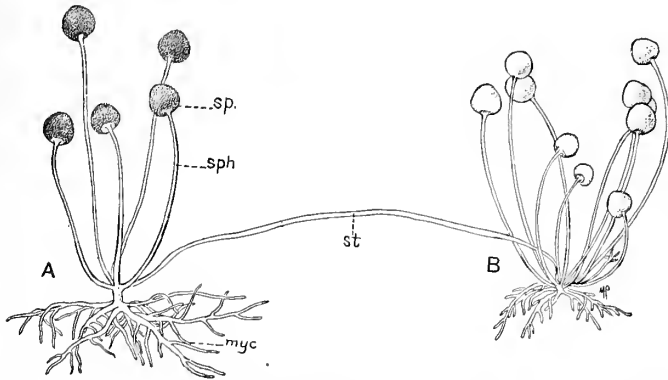


FIG. 79.—Black mold (*Rhizopus nigricans*). A, older plant; *myc.*, mycelia; *sph.*, sporangiophore; *sp.*, sporangium; *st.*, stoloniferous hypha produced by A, and giving rise at its tip to a new plant, B. Greatly enlarged. (Gager.)

of the sporangium is beset with asperites of calcium oxalate. Springing from the base of the sporangiophores or aerial hyphæ one or more stoloniferous hyphæ traverse a portion of the surface of the sub-

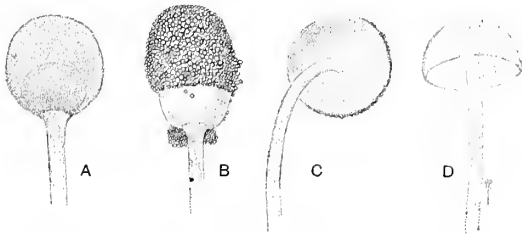


FIG. 80.—*Rhizopus nigricans*. A, Young sporangium, showing columella within; B, older sporangium, with the wall removed, showing ripe spores covering the columella; C, D, views of the collapsed columella after dissemination of the spores. (Gager.)

stratum and their tips, coming in contact with the substratum, swell up forming an adhesive organ or *appressorium* which branches out below into a cluster of spreading submerged hyphæ and above

into several aerial hyphæ bearing sporangia. This method of growth proceeds until the entire surface of the nutritive medium is covered with a dense fluffy mycelium.

*Rhizopus* reproduces by two methods. The most common one is that of internal cell formation. In this asexual method a transverse wall is laid down in the sporangiophore near its tip. The terminal cell thus formed swells up, becoming globular in shape and its protoplasmic contents become changed to form numerous spores within the

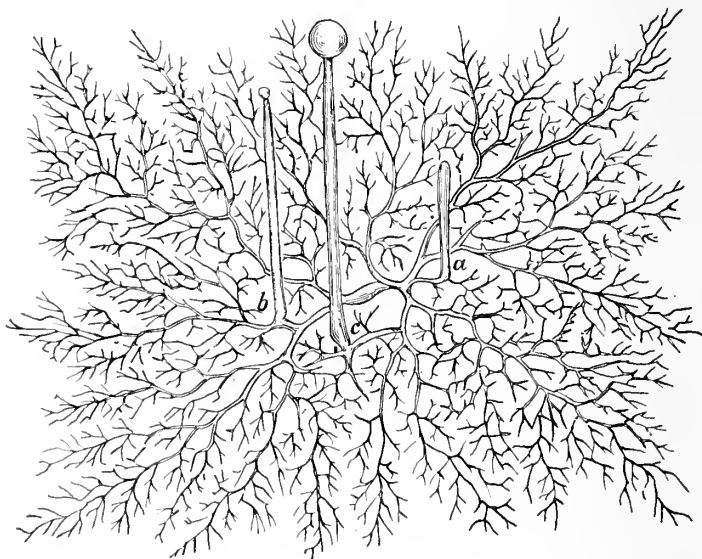


FIG. 81.—*Mucor mucedo*, showing mycelium and sporangiophores. (Palladin.)

wall of the sporangium or enlarged terminal cell of the sporangiophore. The partition wall, separating the lumen of the sporangium from that of the sporangiophore, bulges into the sporangium as a dome-shaped structure which is termed the *columella*. Upon the ripening of the spores the wall of the spore case bursts liberating them. These falling upon moist nutrient substrata, germinate and ultimately form new *Rhizopus* plants. Under certain conditions *Rhizopus* reproduces sexually. Thicker and shorter club-shaped hyphæ arise on opposite branches of the mycelium. A partition wall is

laid down in each of these a short distance from its tip and the contents of each end cell then becomes a gamete or sexual cell. The apical cells of the tips of opposite hyphæ then meet, a solution of the cell walls at the point of contact takes place and the gametes of both end cells fuse to form a *zygospore*. This enlarges and develops a highly resistant wall. After a period of rest, upon coming into contact with a nutrient medium, it germinates into an elongated sporangiophore which develops a sporangium at its summit.

*Mucor mucedo*, another closely allied species, found growing on old nuts, fleshy fruits, bread and horse manure, resembles *Rhizopus nigricans* in many respects but differs from it by the formation of sporangiophores singly instead of in clusters.

*Thamnidium* differs from *Rhizopus* and *Mucor* in the development of two kinds of sporangia, *microsporangia* and *megasporangia*. The sporangiophore produces a terminal large megasporangium possessing a columella and whorls of side branches which bear smaller microsporangia in which the columella is frequently wanting.

#### SUB-CLASS B.—OÖMYCETES

(Sexual apparatus heterogamous)

**Order 1.—Chytridiales.**—Example: *Synchytrium*, a form parasitic on seed plants and forming blister-like swellings.

**Order 2.—Saprolegniales.**—Water molds which attack fishes, frogs, water insects, and decaying plants and animals. Example: *Saprolegnia*.

**Order 3.—Peronosporales.**—Mildews, destructive parasites, living in the tissues of their hosts and effecting pathologic changes. Example: *Albugo*, the blister blight, a white rust attacking members of the *Cruciferae* and *Phytophthora*, producing potato rot.

#### CLASS II.—ASCOMYCETES, THE SAC FUNGI

Mycelium composed of septate filaments and life history characterized by the appearance of a sac called an *ascus* in which *ascospores* are formed. The largest class of fungi.

**Order 1.—Protoascales.**—Plants with asci borne free or at the ends of hyphæ, definite fruiting bodies being absent. Each ascus

usually develops four ascospores. To this order belong *Exoascus*, which is responsible for the abnormal development of tufted masses of branches on a number of trees and shrubs, and the yeasts (Saccharomycetaceæ) many of which produce fermentation.

**Yeasts** are unicellular plants of spheroidal, oval, elliptical, pyriform or sausage shape which reproduce by budding. They occur either in the wild or cultivated condition and are generally found capable of breaking down some form of sugar into alcohol and carbon dioxide.

According to the kind or kinds of sugar fermented Hansen in 1888 classified the yeasts as follows:

1. Species which ferment dextrose, maltose and saccharose: *Saccharomyces cerevisiæ I*, *S. ellipsoideus I*, *S. ellipsoideus II*, *S. pastorianus I*, *S. pastorianus II*, *S. pastorianus III*.

2. Species which ferment dextrose and saccharose, but not maltose: *Saccharomyces marxianus*, *S. exiguus*, *S. saturnus*, *S. Ludwigi*.

3. Species which ferment dextrose, but neither saccharose nor maltose: *Saccharomyces mali Duclauxii*.

4. Species which ferment dextrose and maltose, but not saccharose: *Saccharomyces* n. sp. obtained from the stomach of the honey-bee.

5. Species which ferment neither maltose, dextrose nor saccharose: *Saccharomyces anomalus var. belgicus*, *S. farinosus*, *S. hyalosporus*, *S. membranifaciens*.

The two most important yeasts in the fermentation industries are *Saccharomyces cerevisiæ* and *Saccharomyces ellipsoideus*.

*Saccharomyces cerevisiæ*, commonly called Brewer's Yeast, is a cultivated species with many strains. It is used extensively in the brewing and baking industries and in recent years has met with considerable esteem by the medical profession in the treatment of certain skin diseases.

When examined under the microscope it is found to be somewhat spheroidal to ellipsoidal in outline, 8 to 12 $\mu$  long, and 8 to 10 $\mu$  broad. It consists of an outer cell wall of *fungous cellulose* enclosing cytoplasm and a nucleus, the latter invisible without special staining. The cytoplasm is differentiated into a clear outer membrane lying directly within the cell wall and termed the *ectoplasm* and an inner granular region, the *endoplasm*. In the young condition of the yeast cell numerous glycogen vacuoles are found scattered more or

less uniformly throughout this region but as the cell matures these coalesce, until, in a very old cell, a huge glycogen vacuole may be seen occupying most of the interior, with the cytoplasm and nucleus pushed up against the cell wall and forming there a very narrow layer.

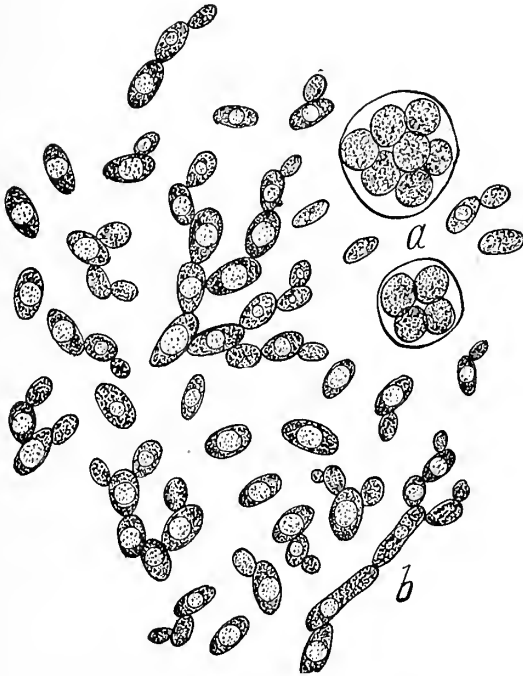


FIG. 82.—Yeast, *Saccharomyces cerevisiae*, the variety known as brewers' bottom yeast; a, spore formation; b, elongated cells. (After Schneider, *Pharmaceutical Bacteriology*.)

Yeast plants grow in dilute saccharine solutions containing dissolved nitrogenous substances such as beerwort, Pasteur's solution, grape juice, etc. Here they are constantly wasting away and as constantly being built up. The question may well arise: "How do they obtain the material necessary for growth and repair?" The answer, in a general way, is not difficult. The fluid in which they live is a solution of sugars and of nitrogenous and other matters.

The cell walls are readily permeable. Food substances diffuse through it into the cell, and by a series of changes (which, indeed, it is no easy matter to understand) are converted into new living substance. The waste products likewise diffuse readily outward. This method of nutrition is called saprophytic, and the yeast plant is said to be a saprophyte.

A striking fact must be briefly mentioned in connection with the metabolism of yeast. Many organisms exercise a profound effect on the medium in which they live. Yeast causes a wholesale destruction of sugar in the surrounding fluid. One of the decomposition products of sugar is alcohol. The alcohol of commerce is produced by the activity of this plant.

*Saccharomyces* has its times of danger and stress when the cells perish in great numbers from cold, starvation, poisons, etc. If not too suddenly exposed, however, they are able to meet adverse conditions by eliminating most of their water, suspending physiological processes, and becoming dormant. Sometimes they enter the resting condition after a process of division, when each cell divides into four parts, each of which becomes nearly dry and is surrounded by a thick wall. Such cells are called *ascospores*, and their production serves both as a method of multiplying the plant and of tiding over adverse conditions. They can survive for a long time without food or water, and can endure higher temperatures than the active cells and almost any degree of cold.

The dried cells and spores float in the air as dust and so accomplish a dispersal of the organism. Doubtless most of them never again meet suitable environment and so sooner or later perish. But some will fall into favorable conditions and be able to multiply enormously again, and so the species is continued.

The general method of reproduction in *Saccharomyces* is that of *gemination* or *budding*. A small protuberance of the cell wall commences to form on the parent-cell. This grows larger and a portion of the cytoplasm and nuclear material pass into it. Eventually a daughter-bud, which may assume the size of the parent-cell, is formed. This generally adheres to the parent-cell and produces one or more granddaughter-buds which in turn may produce great-granddaughter-buds before separation from the parent-cell takes place.

There are two varieties of brewer's yeast, viz.: Top yeasts and Bottom yeasts. Top yeasts grow on or near the surface of the liquid and produce rapid fermentation at summer temperatures causing great quantities of carbon dioxide to arise to the surface and thus forming the froth which is characteristic of ale, stout and porter.

Bottom yeasts grow at about 4°C. at or near the bottom of the vat. They are used in the manufacture of lager beers.

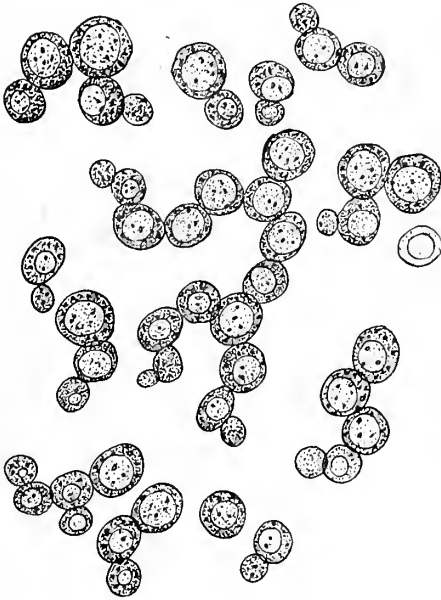


FIG. 83.—*Saccharomyces cerevisiae*. The form or variety known as brewers' top yeast. (Oberhefe.)

*Compressed yeast* (*Cerevisiæ Fermentum Compressum*) N. F. consists of the moist, living cells of *Saccharomyces cerevisiæ* or of other species of *Saccharomyces*, combined with a starchy or absorbent base.

*Saccharomyces ellipsoideus* is a wild species, several varieties of which are found growing on grapes especially in districts where wine is produced. It is termed the true wine yeast to distinguish it

from other wild species found in grape juice, like *S. apiculatus* and *S. membranifaciens* which exert a deleterious effect in wine production. Its cells are ellipsoidal,  $6\mu$  long, occurring singly or in rows of several generations which are rather loosely joined.

**Order 2.—Pezizales** or cup fungi. Examples: *Peziza*, *Lachnea* and *Ascobolus*.

Parasitic or saprophytic plants, whose vegetative bodies consist of a mycelium ramifying through the substratum and whose above ground

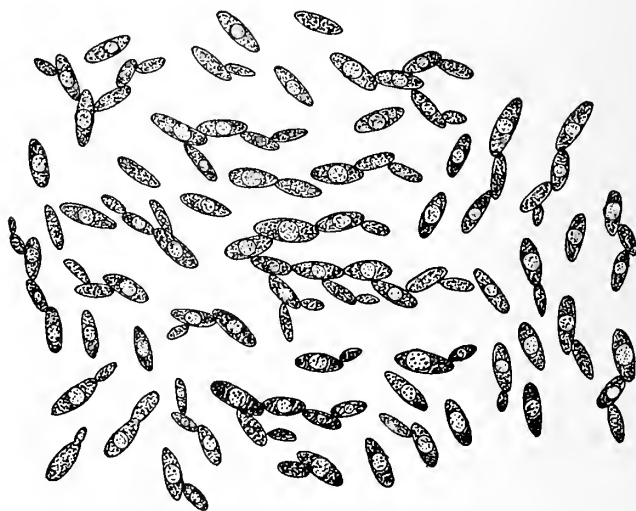


FIG. 84.—*Saccharomyces ellipsoideus*. A common yeast found on grapes, jams, jellies, etc. Budding process is shown in many of the cells as also the vacuoles. (Schneider, *Pharmaceutical Bacteriology*.)

fruiting bodies are sessile or stalked, cup or saucer-shaped structures termed *apothecia* (sing. *apothecium*) in which a fruiting membrane (hymenium) lines the concave upper surface. The asci are usually eight-spored and separated from each other by filamentous structures called *paraphyses*.

**Order 3.—Plectascales**, the blue and green molds. Examples: *Aspergillus* and *Penicillium*.

*Penicillium glaucum* (green mold or mildew), a type of mildew, belonging to the Ascomycetes class of Fungi, forms sage-green crusts



on bread, jellies, old boots, gloves, and various pharmaceutical preparations. It consists of a felt-like mass of interlaced tubular hyphæ called a *mycelium*. From the mycelium numerous hyphæ project into the air and bear a green powder, the spores. These hyphæ are called *aerial hyphæ*. Other hyphæ grow down into the substratum and are called *submerged hyphæ*.

When a small portion of the mycelium is mounted in 10 per cent. alcohol and observed under the high-power objective, it will be noted

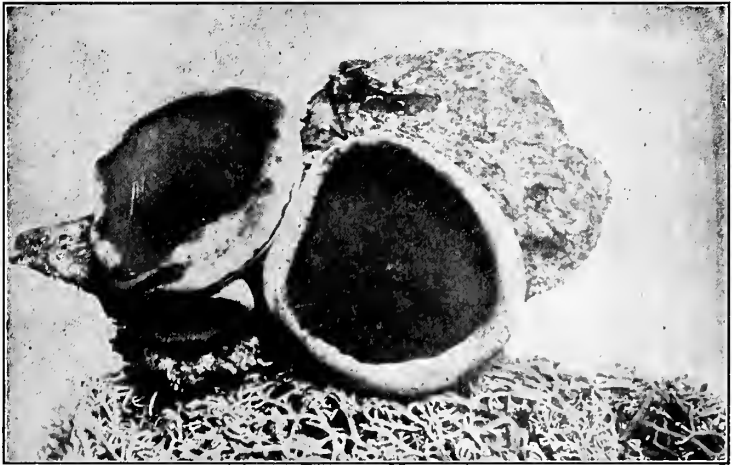


FIG. 85.—Saucer-shaped fruit-bodies of *Peziza repanda*. (Harshberger, from Photo by W. H. Walmsley.)

that each hypha has a transparent wall and protoplasmic contents and is divided by transverse septa into a number of cells. Each cell contains protoplasm, which is differentiated into cytoplasm (cell protoplasm) and several nuclei. In the cytoplasm will be seen several large clear spaces. These are vacuoles and contain water with nutritive substances in solution, called *cell sap*. Each hypha with its branches is clearly distinct from every other one.

The aerial hyphæ bear brush-like branches, which become constricted on their ends into a moniliform aggregation of rounded

spores appearing like a row of beads. Each aerial hypha is composed of a vertical septate branch of the mycelium called the *conidiophore*, branches of this, which are called *secondary conidiophores*, and chains of spores at the tips of *sterigmata* (cells bearing conidia)

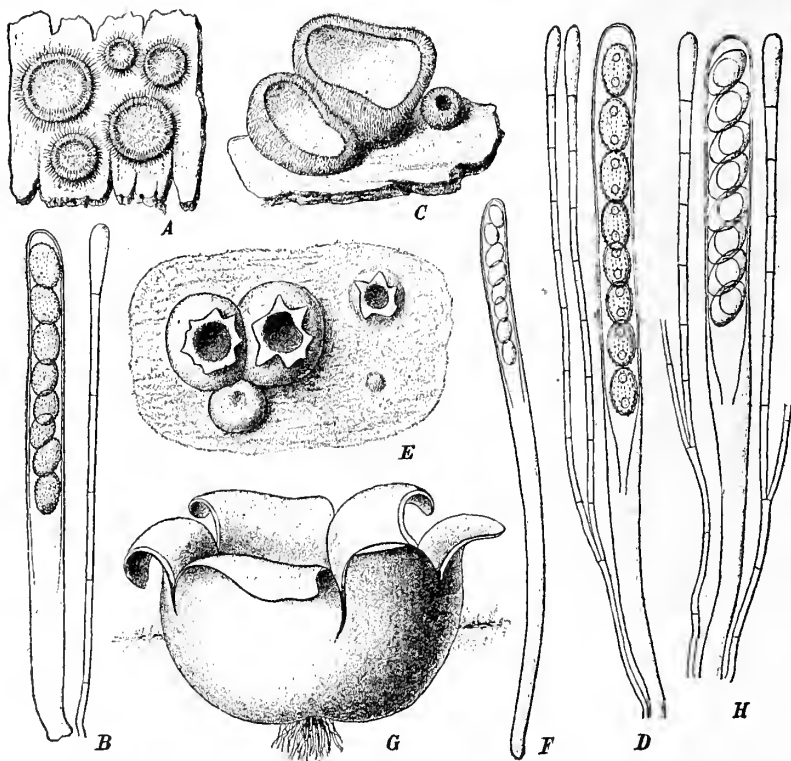


FIG. 86.—A, B, *Lachnea scutellata*. A, Habit; B, ascus with paraphysis; C, D, *Lachnea hemisphaerica*; C, habit; D, ascus with paraphysis; E, *Sarcosphaera arenaosa* habit; F, G, *Sarcosphaera coronaria*; F, ascus; G, habit; H, *Sarcosphaera arenicola* ascus with paraphysis. (See *Die natürlichen Pflanzenfamilien* I, 1, p. 181.) (Harshberger.)

which are called *conidia* or *conidiospores*. The conidia form the loose green powder characteristic of *Penicillium*.

A number of species of *Penicillium* are useful in the arts. *Penicillium roqueforti* is the principal ripening agent of Roquefort,

Gorgonzola and Stilton cheeses. It possesses blue-green globular conidia 4 to  $5\mu$  in diameter.

*Penicillium camemberti* is the principal agent in the ripening of Camembert cheese. It possesses ellipsoidal bluish-green conidia 4.5 to  $5.5\mu$  in diameter.

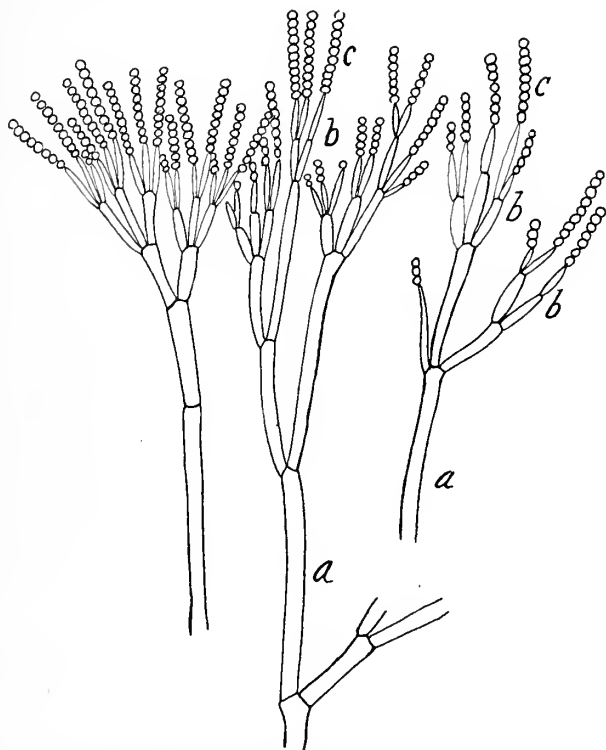


FIG. 87.—Three aerial hyphæ showing the characteristic brush-like branching and spore formation of *Penicillium glaucum*. This fungus is a true saprophyte and is never found on living fruits or vegetables. *a*, Conidiophore branching above into secondary conidiophores; *b*, sterigmata; *c*, conidiospores. (Schneider.)

*Penicillium brevicaulis* grows on old moist paper and has been used to detect the presence of arsenic, for when grown in media containing this element, it develops the compound, diethylarsine. It is yellowish-brown in color and its conidia are rough and spiny.

*Penicillium expansum* is often found on decaying apples where it produces brownish coremia.

*Aspergillus herbariorum*.—This green mold also named *Aspergillus glaucus* and *Eurotium Aspergillus glaucus* is frequently found on fleshy drugs which have not been properly dried. It has also been observed on dried herbarium material, old extracts, on jams, jellies,

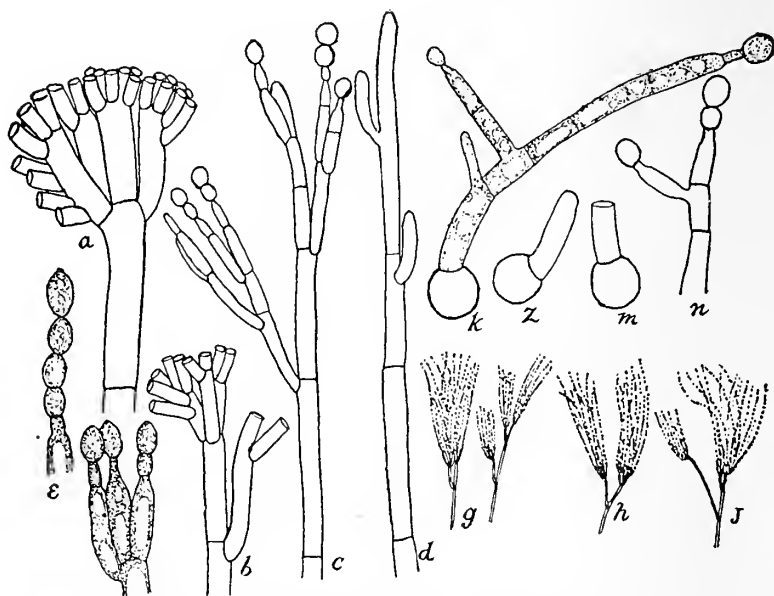


FIG. 88.—*Penicillium Roqueforti*. a, Part of a conidiophore; b, c, other types of branching; d, young conidiophore, just branching, e, f, conidiiferous cells; g, h, j, diagrams of types of fructification. k, l, m, n, germinating spores. (After Thom.)

tobacco, cotton-seed meal, old leather, stale black bread, etc. Like *Penicillium* its vegetative body consists of a mycelium consisting of aerial and submerged hyphæ. It differs from *Penicillium*, however, mainly in not possessing septated conidiophores and by the upper portion of the conidiophores being globular. Upon the globular extremity of the conidiophores are placed numerous elongated sterigmata which bear chains of grayish-green conidia. These are spher-

ical and prickly and range from 7 to  $30\mu$  in diameter. Under certain conditions closed brownish fruit bodies called *perithecia* are produced. These arise on the surface of the substratum from spirally coiled

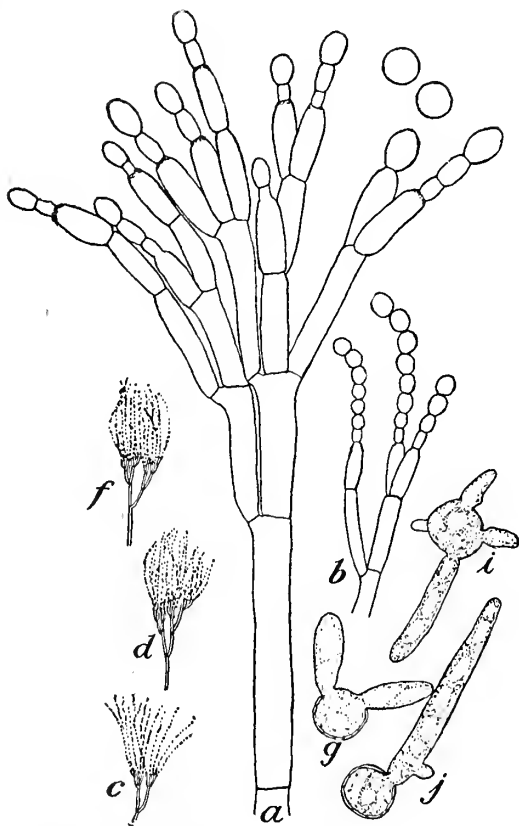


FIG. 89.—*Penicillium Camemberti*. a, Conidiophore with common type of branching with conidiospores; (b), a common less-branched form; c, d, f, diagrams of large fructifications; g, i, j, germinating conidiospores. (From Bull. 82, Bureau of Animal Industry, also After Thom.)

hyphæ and when mature possess numerous *asci*, each of which contains five to eight ellipsoidal *ascospores*.

*Aspergillus oryzae* is a yellowish-green to brown mold which

secretes diastase, a valuable digestive ferment, having the power of converting starch into sugar and dextrin. For centuries the Japanese have employed this species in the preparation of rice mash for Saké, as well as in manufacture of Miso and Soja sauce. The spherical conidiospores are 6 to  $7\mu$  in diameter and of a yellowish-green color.

*Aspergillus fumigatus* is a pathogenic species which produces a disease in birds, horses, cattle and even though rarely in man that is

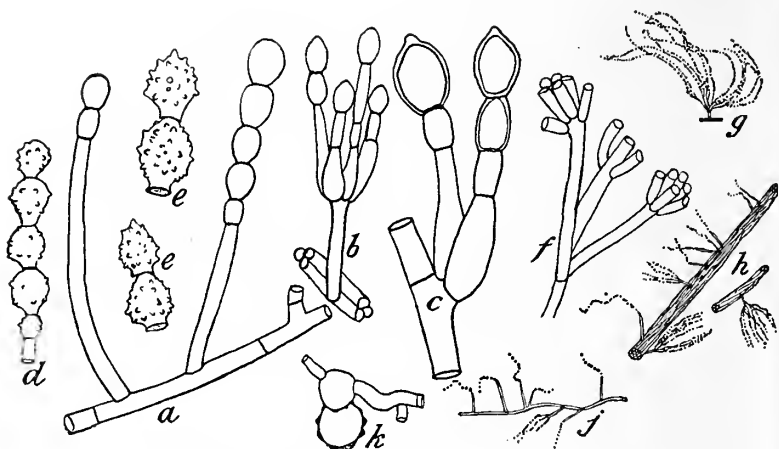


FIG. 90.—*Penicillium brevicaulis*. *a*, Conidiophores and simple chains of conidiospores; *b*, *f*, more complex conidial fructifications; *c*, two young chains of conidiospores; *d*, *e*, echinulate conidiospores; *g*, *h*, *j*, sketches of forms and habits of conidial fructifications; *k*, germinated conidiospores. (After Thom.)

called aspergillosis. The organ most prone to infection by this organism is the lung, although the skin, cornea, ears and other parts are also subject to its parasitic influence. It produces short conidiophores with sterigmata bearing long chains of rounded, colorless conidia 2.5 to  $3\mu$  in diameter. Harshberger<sup>1</sup> cites the presence of perithecia in this organism which are nut-brown, globular, 250 to  $350\mu$  in diameter, and inclose oval thin-skinned asci with eight red lenticular ascospores each of which has a diameter of 4 to  $4.5\mu$ .

*Aspergillus niger* (*Sterigmatocystis niger*) develops dark brown

<sup>1</sup> "Mycology and Plant Pathology," p. 147.

mycelial masses in which are to be noted slender conidiophores bearing handle-shaped, branched sterigmata that cut off from their tips

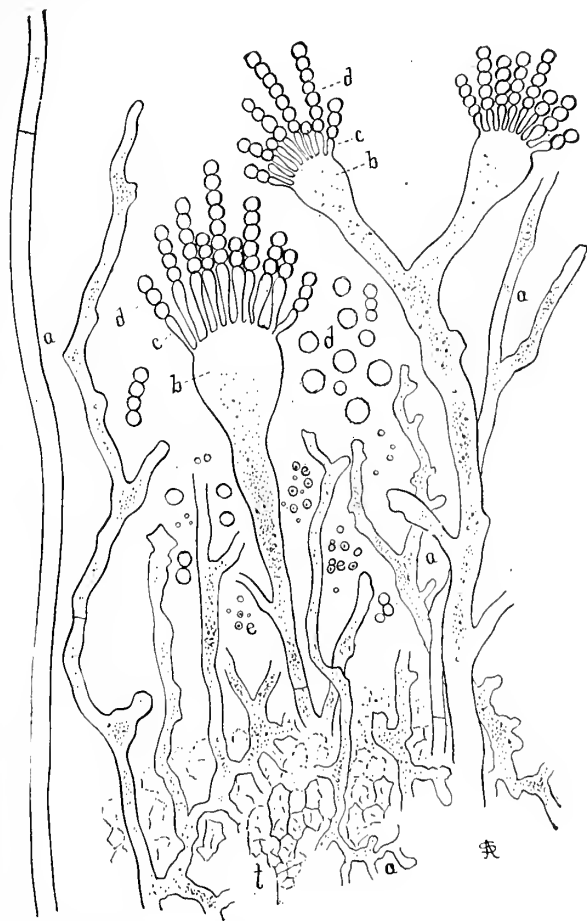


FIG. 91.—*Aspergillus oryzae* associated with yeasts in the making of the Japanese beverage Saké. Vegetative hyphæ (a) and spore-forming hyphæ (b, c, d) are shown. (Schneider, *Pharmaceutical Bacteriology*.)

chains of rounded black-brown conidia 3.5 to 5 $\mu$  in diameter. This fungus has been found to produce suppurative inflammation of the ex-

ternal and middle portions of the human ear. It is also a cause of cork disease, so often imparting a disagreeable taste to bottled beverages.

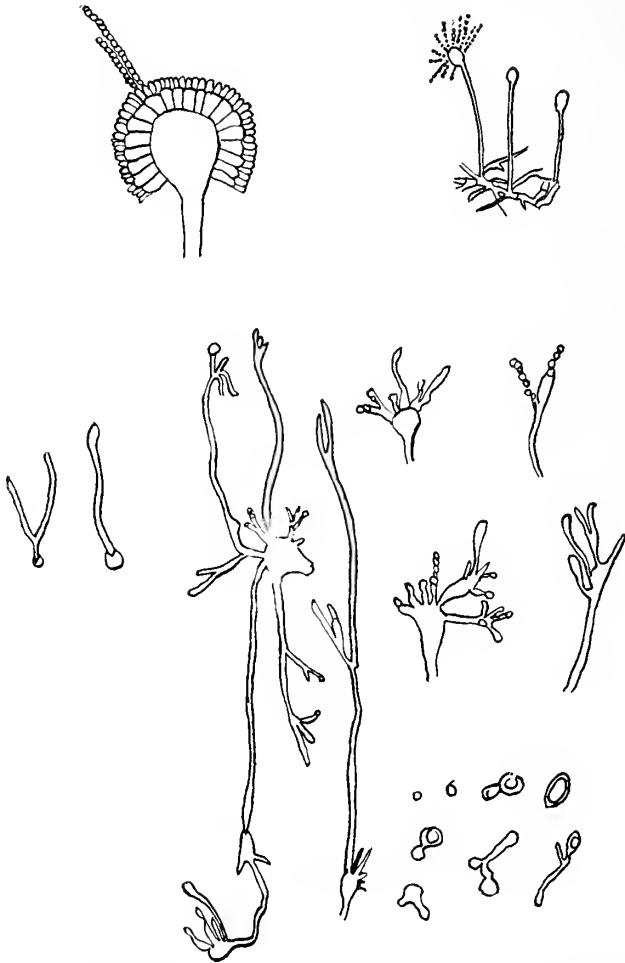


FIG. 92.—*Sterigmatocystis niger* (*Aspergillus niger*) showing conidiophores and conidiospore formation with stages in germination of spores. (Harshberger, after Henri Coupin.)

**Order 4.—Tuberales**, the truffles. Fungi whose septate mycelium is often connected with the roots of trees forming the structure



known as *mycorrhiza*. Several species of the genus *Tuber* growing in woods of France, Germany and Italy produce tuberous subterranean bodies called Truffles, which are highly prized as a table delicacy by the inhabitants of these countries.

**Order 5.—Helvellales**, the saddle fungi. Fleishy fungi entirely saprophytic, living attached to leaf mold or growing in humous soil or, in a few cases, on decaying wood. The fleshy fruiting bodies (ascocarps) are divided into stalk (*stipe*) and cap (*pileus*) portions.



FIG. 93.—The morel, *Morchella esculenta*. (Gager, from photo by W. A. Merrill.)

The external surface of the cap is covered with a layer of asci and paraphyses which together constitute the ascigeral layer. To this group belong the Morels and the Earth Tongues.

One of the Morels, *Morchella esculenta*, is frequently found in fire-swept woods. Its fruiting body consists of a hollow, externally ridged stipe, bearing upon its summit a fleshy pileus whose outer surface is honeycombed with ridges and depressions. The depressions are covered with an ascigeral layer composed of asci and paraphyses. This species is edible.

**Order 6.—Pyrenomycetales**, the mildews and black fungi common as superficial parasites on various parts of plants. To the black

fungi division of this order the Ergot fungus, *Claviceps purpurea*, belongs.

**Life History of *Claviceps Purpurea*.**—Through the agency of winds or insects the spores (ascospores or conidia) of this organism are brought to the young ovaries of the rye (*Secale cereale*). They germinate into long filaments called hyphæ, which, becoming entangled to form a *mycelium*, spread over the ovary, enter it superficially, secrete a ferment, and cause decomposition of its tissue and the resultant formation of a yellow-mucus substance called honey-dew, which surrounds chains of moniliform reproductive bodies known as conidia. The honey-dew attracts certain insects which disseminate the disease to other heads of grain.

The mycelial threads penetrase deeper and deeper into the ovary and soon form a dense tissue which gradually consumes the entire substance of the ovary and hardens into a purple somewhat curved body called a *sclerotium*, or official ergot—the resting stage of the fungus, *Claviceps*.

The ergot falls to the ground and in the following spring sprouts into several long stalked, globular heads called *stromata* or *ascocarps*. Each (fruiting) head or ascocarp has imbedded in its surface numerous flask-shaped invaginations called *perithecia*, from the bases of which several sacs or *asci* develop. Within each ascus are developed eight filiform spores (*ascospores*) which, when the ascus ruptures, are discharged and are carried by the wind to other fields of grain, there to begin over a new life cycle.

### CLASS III.—BASIDIOMYCETES, OR BASIDIA FUNGI

This large class of fungi, including the smuts, rusts, mushrooms, gill and tooth fungi, etc., is characterized by the occurrence of a basidium in the life history. A *basidium* is the swollen end of a hypha consisting of one or four cells and giving rise to branches called sterigmata, each of which cuts off at its tip a spore, called a *basidiospore*. In addition to the basidiospores, some forms also produce spores termed *chlamydospores*.

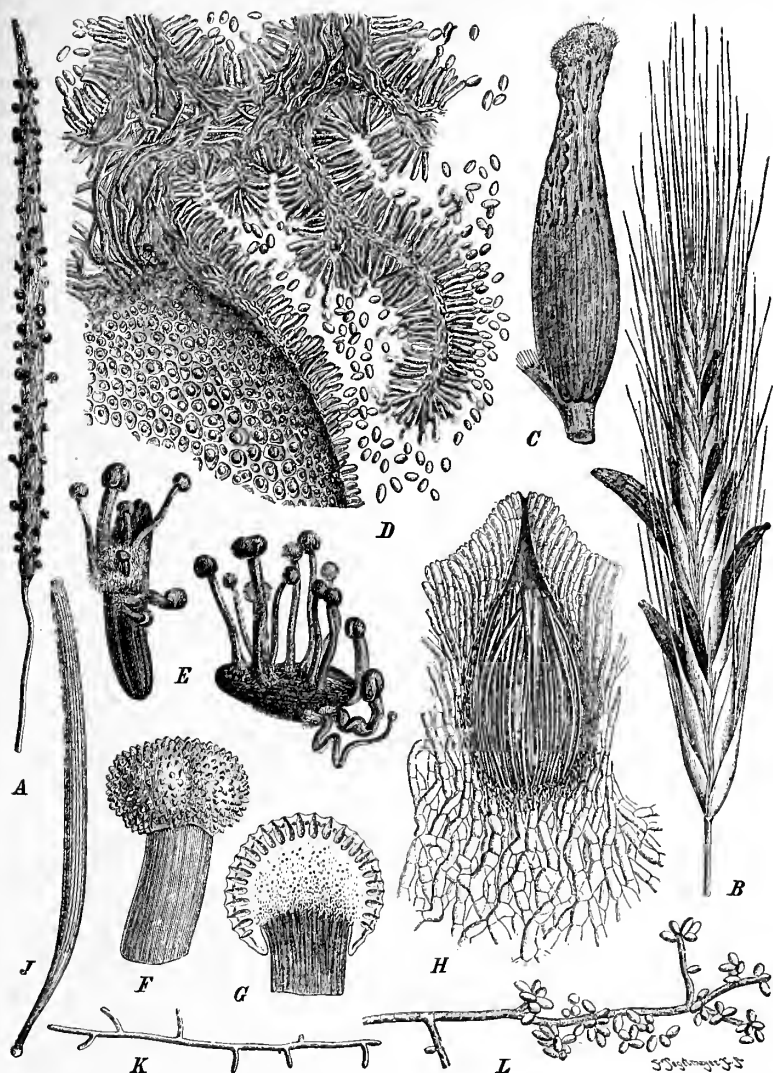


FIG. 94.—A, *Balansia claviceps* on ear of *Paspalum*; B–L, *Claviceps purpurea*; B, sclerotium; C, sclerotium with *Sphacelia*; D, cross-section of sphacelial layer; E, sprouting sclerotium; F, head of stroma from sclerotium; G, section of same; H, section of perithecium; J, ascus; K, germinating ascospore; L, conidiospores produced on mycelium. (See *Die natürlichen Pflanzenfamilien* I, 1, p. 371.)

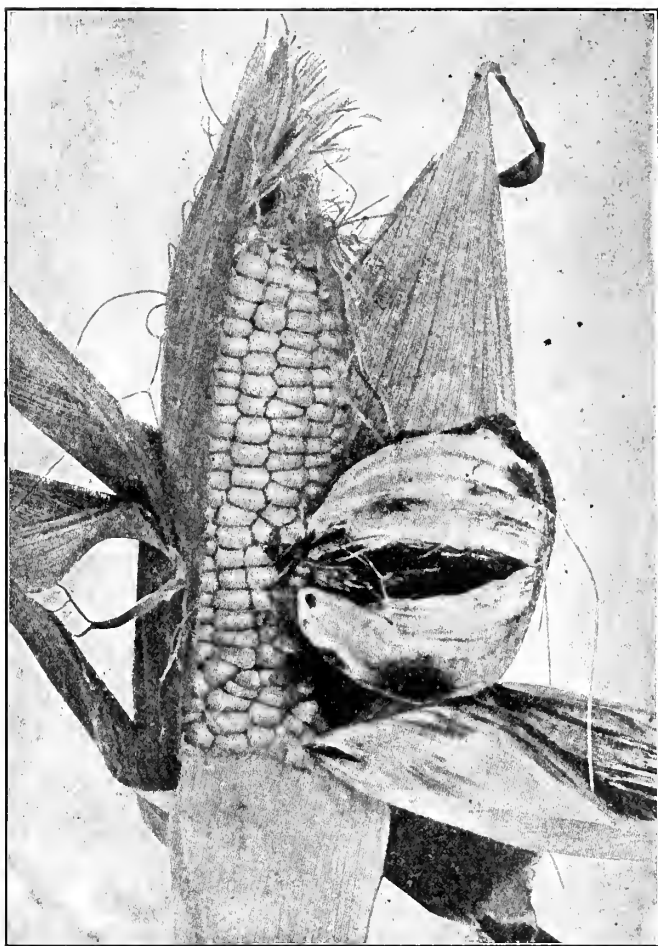


FIG. 95.—Smut boil of *Ustilago zeæ* on ear of corn, developed from one infected kernel. (After Jackson, F. S., Bull. 83, Div. Coll. Agric. Exper. Stat., December, 1908.)

## SUB-CLASS A.—PROTOBASIDIOMYCETES

(Basidium four-celled, each cell bearing a spore)

**Order 1.—Ustilaginales, the smuts.** Destructive parasites which attack the flowers of various cereals, occasionally other parts of these plants. Example: *Ustilago Maydis*, the corn smut. The basidiospores in this group are borne on *promycelia*.

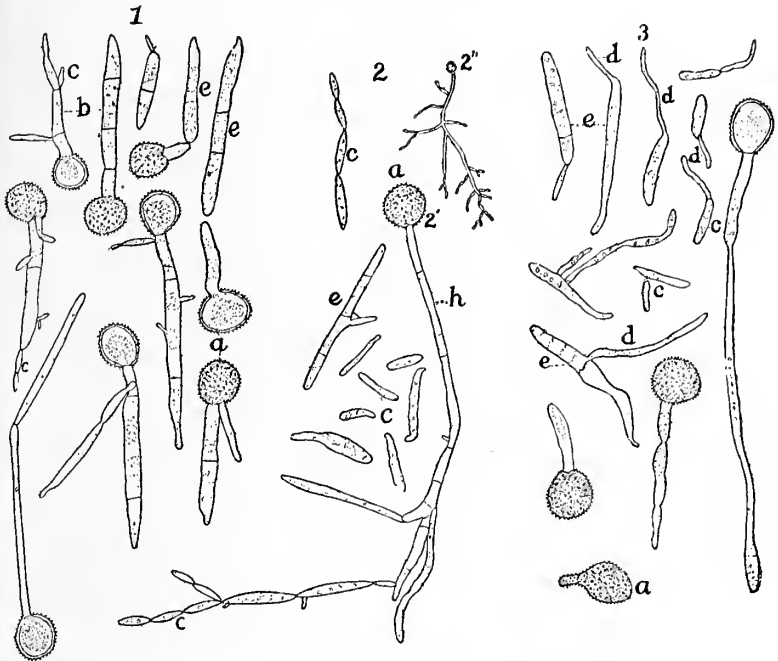


FIG. 96.—Germination of the chlamydospores of corn smut (*Ustilago zeae*); 1, Various stages in germination from corn 3 days after being placed in water; 2, spores germinated in contact with air; 3, several days after spores were placed in  $\frac{1}{20}$  per cent. acetic acid, formation of infection threads. a, Spores; b, promycelia; c, basidiospores; d, infection threads; e, detached pieces of mycelia. (After Bull. 57, Univ. Ill. Agric. Exper. Stat., March, 1900.)

**Ustilago Maydis (Ustilago Zeae) (Corn Smut).**—Corn smut is a destructive parasite which for a long time was supposed to be confined to the Indian Corn, but which now is known to occur on Mexican Grass. It is the only smut useful in medicine. The

mycelium of the fungus extends through all parts of the infected host through the intercellular air spaces and produces large tumor-like masses on the ears, tassels, husk, leaves and stem. Each mass is filled with spores and covered with a tightly appressed membrane which has a whitish appearance like German silver. The spores are at first a dark olive-green, but on maturity are dark brown. They are sub-spherical and show prominent spines. They arise by the division of the septate mycelium into thick-walled echinulate resting spores called *chlamydospores* or *brand spores*. These spores fall to the ground and pass the winter. In the spring each germinates into a three- or four-celled filament called a *promycelium*, from the cells of which *basidiospores* arise. The basidiospores develop a mycelium which penetrates the seedling of the host plant.

**Order 2.—Uredinales**, the rusts. Obligate parasites possessing a septated branched mycelium which ramifies through the intercellular-air-spaces of the host and sends haustoria into the cell cavities. The different stages of their life cycle are either restricted to one host or distributed between two or more hosts. An outline of the life history of the wheat rust will give an idea of the peculiarities of the group.

**The Wheat Rust (*Puccinia Graminis*)**.—If we examine the wheat plant just before harvest we will find on the stems and leaves some rust-red lines. The presence of the mycelium of the fungus in the intercellular spaces of the host does not kill the host directly or appear to stunt its growth, but the effect of the parasite on the host is seen when the grains mature. The grains are small and mushy, due to the fact that the nutrition of the host had been disturbed and the formation of starch in the grains inhibited. The mycelium is localized and gives rise underneath the epidermis to rounded egg-shaped spores attached to it by short pedicels. The spores are produced in such numbers that the space beneath is too confined. As the long epidermal cells of grasses run longitudinally, the pressure of the spore masses from within causes the epidermis to crack and its edges become turned back. Through the resultant cleft the *summer spores* or *uredospores* are thrust out. These uredospores are orange-brown in color and covered with minute spines. The mass of them has been called a *uredinium*. These spores are

detached from the pedicels and blown by the wind to healthy plants. After summer is over and dry weather comes on, an examination of stubble in the field (blades of grass and stems of wheat left carelessly), these rust-red lines are replaced by brownish-black spores called *teleutospores* (teliospores). A mass of these is known as a telium.

The summer stage on wheat is known as *Uredo linearis*.

The autumn stage on wheat is known as *Puccinia graminis*.

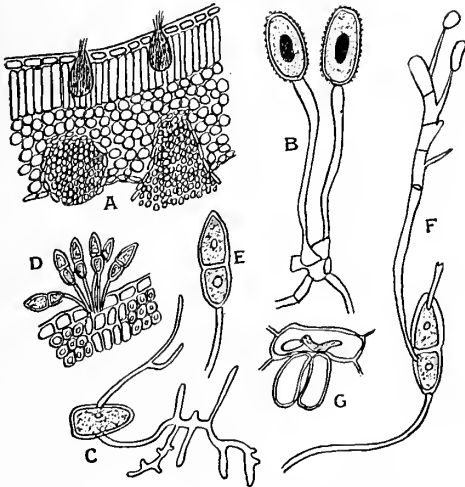


FIG. 97.—Spore forms of wheat rust, *Puccinia graminis*. A, Section through barberry leaf showing pycnia on upper surface and aecia on lower; B, two urediniospores; C, germinating urediniospore; D, teliosorus showing several teliospores; E, single two-celled teliospore; F, germinating teliospore with four-celled basidium and two basidiospores; G, basidiospore growing on barberry leaf. (Harshberger, adapted from deBary.)

The teleutospores are two-celled and have thick walls and persistent pedicels. They remain attached to the stubble until the following spring and then either one or both cells composing them produce an outgrowth known as a promycelium (nothing but a basidium divided transversely into four cells). Each cell of the basidium is capable of producing a branch, at the tip of which a basidiospore is formed. These basidiospores are blown to the Barberry (*Berberis*) and infect the leaves of this plant. The mycelium runs in the intercellular air spaces and causes the appear-

ance of a number of small depressions on the upper side of the leaf. These in section are a rich chocolate brown and known as *spermagonia*. In the center of a spermagonium are produced hyphæ, which project out to its orifice and obstruct off minute spores called *spermacia*. On the opposite side of the leaf cup-shaped depressions are formed, each with a limiting membrane (peridium). Within the cup-shaped depression thousands of spores are formed in chains closely packed together. These are the æcidiospores (æciospores). The cluster cup is called an *Æcidium* (*Æcium*). These æciospores are conveyed to wheat and cause infection, thus completing the life cycle.

**Order 3.—Auriculariales.**—The so-called “ear fungi” which occur on the bark of many plants, on wooden fences, etc., as auriculate growths which when young are jelly-like and brilliantly colored, when old, hard, grayish and considerably wrinkled. The ear-like fruiting body is known as the *sporophore*. Its internal surface is lined with a hymenium or fruiting body consisting of numerous four-celled basidia, each of which cuts off at its tip a basidiospore.

**Order 4.—Tremellales.**—Saprophytes which live on decaying wood as moist, soft, quivering, gelatinous growths becoming later dry and horny.

#### SUB-CLASS B.—AUTOBASIDIOMYCETES

(Mostly fleshy forms characterized by one-celled basidia with generally four, occasionally six, eight or two sterigmata each of which cuts off a basidiospore at its tip.)

#### Division a.—Hymenomycetes

(Hymenium or spore-bearing surface exposed)

This division of Autobasidiomycete or higher basidiomycete fungi comprises the following orders: Dacromycetales, Exobasidiales, Thelephorales, Clavariales and Agaricales.

**Order 1.—Dacromycetales.**—This order includes the “weeping fungi.” One of the most common is *Dacromyces deliquescens* which occurs as a gelatinous body of bright red color on dead wood. The basidiospores are formed during a wet period and the fungus swells up in the water forming a slimy mass. In addition to basidiospores



the mycelium may break up into oidiospores, if the wet period is prolonged. In consisting of slimy gelatinous masses the "weeping fungi" approach the *Tremellaceæ* but are distinguished from them in the basidium being undivided in the former and divided in the latter.

**Order 2.—Exobasidiales.**—This group is found growing parasitically on shrubs especially those of the heath family. The mycelium

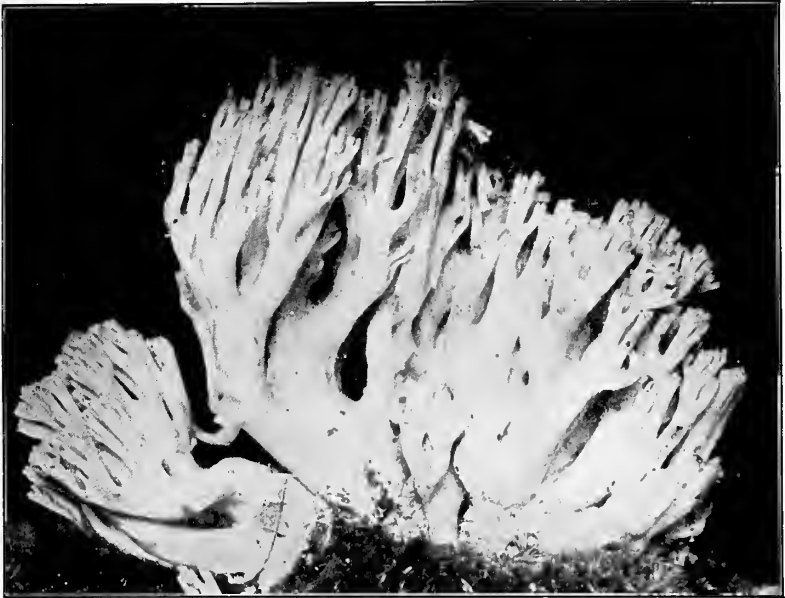


FIG. 98.—Coral-like fruit-bodies of *Clavaria flava*. (Harshberger, from Photo by W. H. Walmsley.)

lives in the tissues of the stems, leaves, sepals and petals and produces spongy fleshy yellowish or brownish galls which are popularly called "Azalea apples." The galls are edible. They are covered with a hymenium.

**Order 3.—Thelephorales**, forms appearing on tree trunks as leathery incrustations or as bracts on the ground, old logs, etc.

**Order 4.—Clavariales**, the coral or fairy club fungi. Fleshy coral or club-shaped forms, all of which are saprophytes found in woods

growing in bunches out of leaf mold. They are all edible and of a white, yellow or some other brilliant color.

**Order 5.—Agaricales**, the mushroom or toadstool alliance. Alike with the other members of the Basidiomycetes, the plant body consists of the mycelium, ramifying through the substratum, but the part which rises above the surface (the Sporophore) is in most cases differentiated into a stalk-like body called a stipe bearing upon its summit a cap or pileus, the latter having special surfaces for the hymenium.



FIG. 99.—*Boletus felleus* in three stages of development. (After Patterson, *Flora W. and Charles, Vera K.*, Bull. 175, U. S. Dept. Agric., pl. xxxi, Apr. 29, 1915.)

**Family I.—Hydnaceæ**, or tooth fungi. This group is characterized by the hymenium being placed over purple-like, spiny or long digitate projections of the pileus. Many of the species of the genus *Hydnum* are edible.

**Family II.—Polyporaceæ**, or pore fungi. The sporophores or fruiting bodies of these fungi are various. They may be entirely

supinate with pores or shallow depressions on their upper surfaces (*Merulius*), or mushroom-like (*Boletus*), or of the nature of woody (*Fomes*) or fleshy (*Fistulina*) brackets. In all cases the hymenium or basidial layer lines the inner surface of pores.

The sporophore of *Polyporus officinalis* when deprived of its outer rind and dried constitutes the official N. F. drug *Agaricus*. This species grows abundantly on various species of pines, spruces and larches.

**Family III.—Agaricaceæ**, the gill family, in which the hymenium covers blade-like plates of the pileus, called *gills*, generally occurring on the under surface of the same. Examples: *Agaricus campestris*, the common edible mushroom of fields; *Amanita muscaria* and *Amanita phalloides*, both of which are poisonous.

**Agaricus Campestris (Common Mushroom).**—This plant is an edible gill fungus which grows in open, grassy fields during late summer and early autumn. It is never found in the forest or on trees or fallen trunks, seldom in the mountains. The cultivated form grows in specially constructed houses made of boards. A corridor runs through these houses so that the mushroom beds can be easily reached. In the growth of mushrooms tons of horse manure are used. This is covered with loamy soil  $1\frac{1}{2}$  inches thick. The whole mass is compacted together. Into the resultant beds is introduced English-grown spawn, which comes in flat brick-shaped masses (horse manure through which mycelium has grown). Pieces of these "bricks" are put in the horse manure bed only after the heat has first disappeared. The beds are then watered well and in a short time the *sporophores* or fruiting bodies of the fungus spring up.

The mycelium or vegetative body of *Agaricus* which develops in the soil from spores (basidiospores) is white and thready. On this mycelium develops little buttons, first about the size of a pin head, becoming later pea size and then assuming a pear-shaped form. At this stage the sporophore consists of a cylindrical solid stipe or stalk and a pileus or cap. The border of the pileus is joined to the stipe by means of a "*partial veil*." Within this veil is found a circular cavity, into which the *gills* grow. At first the stipe grows faster than the rest of the fruiting body. The pileus expands transversely and the gills keep pace. After a while the veil ruptures, leaving a portion

attached to the stipe. This constitutes the *annulus* or *ring* (true annulus). The hyphæ in the pileus form the *Tela contexta*. If we make a section through a gill, the hyphæ are seen to run longitudinally. The central part is called the *trama*; next and outside trama is the *sub-hymenium*; next, *hymenium*, consisting of *basidia* (hence a basidial layer). Each basidium bears one or two little points known as *sterigmata*. Each sterigma bears a purplish-brown basidiospore. The basidiospores falling to the ground germinate into hyphæ and these become interlaced to form a mycelium.



FIG. 100.—Meadow mushroom (*Agaricus campestris* L.). A, view showing under side of pileus; g, gills; a, annulus, or remains of the veil attached to the stipe; B, side view; s, stipe; a, annulus; p, margin of pileus, showing at intervals the remains of the veil. (Gager, after W. A. Murrill.)

In the wild mushroom the gills are at first pink, in cultivated, fawn-colored. Ultimately in wild form the gills turn brownish. The spores are purplish-brown. The color of the stipe and upper surface of the pileus varies from whitish to a drab color.

**The Amanitas (Poisonous Fungi).**—*Amanita muscaria* and *Amanita phalloides*, commonly known as the “fly agaric” and the “deadly agaric” respectively, are very poisonous forms. *Amanita muscaria* is common in coniferous forests, although may occasionally be found

in grassy places. It occurs singly and not in groups. *Amanita phalloides* is found in woods and borders of fields and, like the fly agaric, occurs singly and not in groups.

Each of these have fruiting bodies (sporophores), which begin at the surface of the ground as a button similar to that of the edible mushroom. This enlarges and assumes a dumbbell shape. The whole button is covered by an outer veil, known as the *velum univ-*



FIG. 101.—Deadly amanita (*Amanita muscaria*) showing volva at base of stem and frill, like stem ring. (After Chestnut, V. K., *Bull.* 175, *U. S. Dept. Agric., pl. i*, Apr. 29, 1915.)

*sale*, which encloses the pileus, gills and stipe. As the stipe lengthens more rapidly than the pileus, the upper part of the veil is stretched and finally breaks in its middle portion. The lower part remains as a cup, out of which the stipe grows. The upper part is carried up as shreds adhering to the margin of the pileus. The lower part is called the *volva* or death cup. The annulus present is a false annulus, for it represents a peeling down of the upper part of the stipe. Both have chalk-white gills, a white stipe, and white spores.

The pileus of *Amanita muscaria* is yellow, or orange-red; the surface is smooth, with prominent warty scales.

The pileus of *Amanita phalloides* varies from dull yellow to olive to pure white. It does not possess the warty scales found in the *Amanita muscaria*, but occasionally has a few membranous patches.



FIG. 102.—The deadly amanita, *Amanita phalloides*. Note the cup at the base of the stipe. (Gager, from photo. by E. M. Kittredge.)

#### Division b.—Gasteromycetes

(Hymenium inclosed)

**Order 1.—Lycoperdales**, or puff ball alliance. This order includes a number of interesting parasites and saprophytes the most common of which are the earth stars belonging to the genus *Geaster* and the puff balls, the most common form being *Lycoperdon*. In these, the

fruiting sporophore consists for the most part of a shell-like covering called the *peridium*, composed of an outer layer or *exoperidium* and an inner layer or *endoperidium*. The peridium in the unripe condition of the sporophore covers a mass of soft cellular tissue called the *gleba*. Upon the ripening of this mass, the interior is seen to be divided into many-branched compartments that are separated from each other by walls made up of branched hyphæ. These walls are lined with a hymenium composed of many basidia, each of which constricts off usually four basidiospores. The earth stars differ from the puff balls in possessing an outer wall or exoperidium which splits in star-shaped fashion.

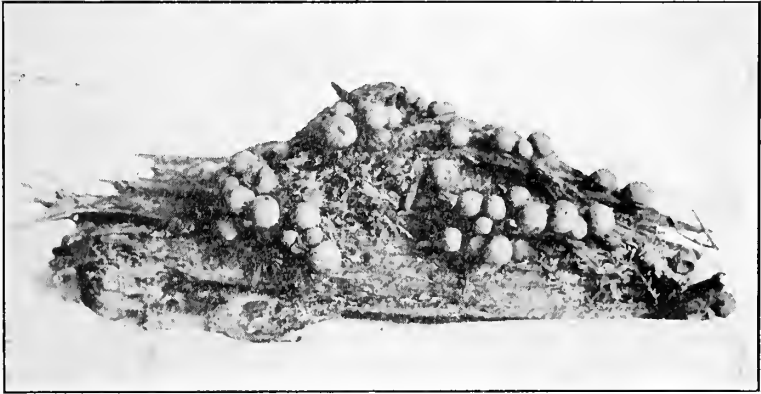


FIG. 103.—A colony of Puff Balls, *Lycoperdon*, growing saprophytically upon a portion of a rotten log. (Photograph by author.)

**Order 2.—Nidulariales**, the nest fungi. A group of Gasteromycetes whose sporophores are crucible- or crater-like. These arise from a subterranean mycelium and show an outer and inner peridial layer. The outer peridium is roughened at its base. The inner peridium is leathery and may or may not be continued over the top. When mature the crucible-like body shows black seed-like bodies inside which resemble eggs in a bird's nest. Each one of these is connected with the inner peridium by a cord which resembles the umbilical cord of an animal. These inner bodies are called *peridiola* (sing. *peridiolum*). Each peridiolum consists of a hard glistening

outer layer and a spongy inner layer surrounding a cavity into which basidia and basidiospores project. These fungi are found in stiff clayey soil.

Order 3.—**Phallales**, the carrion or stink-horn fungi. This, the highest group of the Autobasidiomycetes, consists of highly and characteristically colored forms which, when mature, emit most vile and penetrating odors. The fruiting body, in each instance, begins as an egg-shaped structure which starts its growth from a widely spread underground mycelium of chalky-white color. As the "eggs" enlarge they push above the surface of the ground. The central portion, elongating, then breaks through the outer or peridial portion, which remains as a cup or volva at the base of the mature fruit body. Upon the summit of the central stalk rests the cup-like many-chambered gleba. The basidiospores are imbedded in a greenish fetid slime formed by a mucilaginous disintegration of the substance of the hymenium. This fetid green material is attractive to carrion flies which visit the plants and remove the material with its embedded spores. The latter will not germinate until after passing through the alimentary canal of these flies.



FIG. 104.—Mature stink-horn, *Dictyophora duplicata*. (Harshberger, from photo. by W. H. Walmsley.)

#### CLASS IV.—FUNGI IMPERFECTI

An assemblage of varied forms, the life histories of most of which are imperfectly understood. In this group are included numerous parasites which produce diseases in crop plants.



## SUBDIVISION V.—LICHENES, THE LICHENS

Lichens are variously colored, usually dry and leathery plants, consisting of symbioses of algæ and fungi. In each case the fungus derives its food from materials manufactured by the algæ and in return extracts water from the substratum and shares it with the algæ. The association is therefore mutually beneficial. Blue-green and Protococcus forms of Green Algæ and Ascomycete Fungi are for the most part concerned in lichen formation.

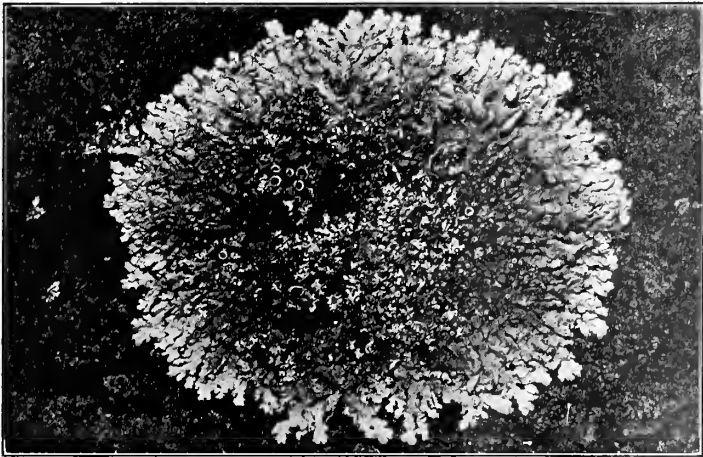


FIG. 105.—A foliaceous lichen, *Physcia stellaris* (L.) Nyb., growing on a rock. The cup-shaped structures are the fruiting bodies (apothecia). At the left are seen two very young plants. (Gager.)

Lichens are found on the bark of trees, on rocks, logs, old fences, etc. The body of a lichen shows a differentiation into two regions: a more or less compact row of cells on both surfaces, called the epidermis; and an inner portion composed of the mycelium of the fungus. The alga is imbedded in this portion. In most cases the spores are borne in asci, which are themselves found in closed or open *Apothecia*.

Scales or *soredia* are found on many lichens. These consist of a network of hyphæ enclosing algal cells. By becoming detached from the parent plant, they develop new lichens and so constitute a means of vegetative propagation.

According to the manner of growth of the thallus and nature of attachment to the substratum, three different sub-groups of lichens may be distinguished, viz.: (1) Foliaceous where the thallus is flat, leathery and leaf-like and attached to the substratum at different points. To this group belong *Physcia* and *Parmelia*. (2) Crustaceous, where the thallus closely adheres to rocks and bark of trees. To this group belong *Graphis* and *Pertusaria*. (3) Fruticose, where the thallus is upright and branching. To the last group belong *Cetraria islandica*, species of *Cladonia*, and *Usnea*.



FIG. 106.—*Cetraria islandica*. (Sayre.)

To the pharmacist and chemist lichens are chiefly of interest because of the coloring principles which they contain. Species of *Lecanora* and *Rocella tinctoria* yield, when subjected to fermentation, the dyes orcein and litmus. Litmus is one of the best indicators in volumetric analysis. Cudbear, a purplish-red powder, used extensively for coloring pharmaceutical preparations in the form of tincture, is prepared by treating species of *Rocella*, *Lecanora* or other lichens with ammonia water. Other lichens, such as *Cetraria islandica*, various species of *Parmelia*, *Usnea* and *Alectoria*, have been used in medicine because of demulcent principles which they contain.

## DIVISION II.—BRYOPHYTA

Plants showing a beginning of definite alternation of generations, *i.e.*, gametophyte (sexual phase) alternating with sporophyte (asexual phase of development) in their life history, the two phases being combined in one plant. The female sexual cell is always lodged in an *archegonium* (a multicellular female sexual organ).

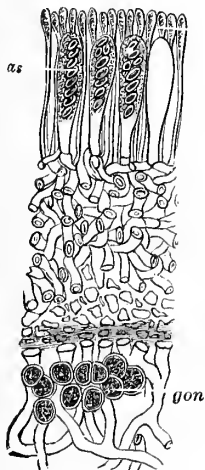


FIG. 107.

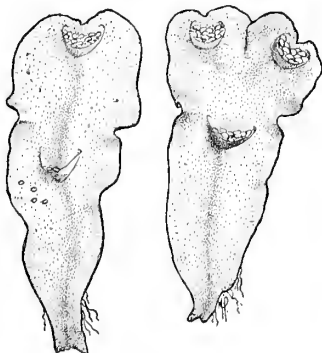
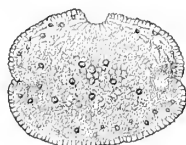


FIG. 108.

FIG. 107.—Section of thallus of *Cetraria islandica* through an apothecium. *as*, Asci, three of which contain ascospores. *gon*, Gonidia. The inner (central portion) shows the mycelial threads of a fungus entangling the alga. (*Sayre.*)

FIG. 108.—A liverwort (*Lunularia*). Below, portions of the thallus, showing the lunar-shaped cupules, with brood-buds, or gemmæ. Above a single gemma, greatly magnified. (*Gager.*)

## SUBDIVISION I.—HEPATICÆ OR LIVERWORTS

Plants of aquatic or terrestrial habit whose bodies consist of a rather flat, furchate branching thallus or leafy branch which is dorsoventral (having distinct upper and lower surface); the upper surface consists of several layers of cells containing chlorophyll, which gives the green color to the plants; the lower surface gives origin to hair-like outgrowths of the epidermal cells serving as absorptive parts and called *rhizoids*. Upon the dorsal surface of this thalloid body

(the gametophyte) cup-like structures are produced called *cupules* which contain special reproductive bodies called *gemmae*, these being able to develop into new gametophytes. The sex organs are of two kinds, male and female. The male organs are termed antheridia, the female, archegonia. The antheridia are more or less club-shaped, somewhat stalked organs consisting of an outer layer of sterile cells investing a mass of sperm mother-cells from which are formed the spirally curved biciliate antherozoids, or male sexual cells. The archegonia are flask-shaped organs consisting of an investing layer of sterile cells surrounding an axial row of cells, the neck-canal cells, ventral-canal cells and the egg or female sexual cell. Every cell of the axial row breaks down in the process of maturation with the exception of the egg which remains in the basal portion. Both antheridia and archegonia generally arise on special stalks above the dorsal surface. After the egg is fertilized by an antherozoid, the young embryo resulting grows into a *sporogonium* (the sporophyte) consisting of a stalk portion partly imbedded in the archegonium surmounting a sporangium or capsule in which spores are produced. When mature the capsule splits open discharging the spores. The spores on germination develop into a *protonema* or filamentous outgrowth which later develops the thallus.

**Order 1.**—**Marchantiales**, including *Marchantia* and *Riccia*.

**Order 2.**—**Jungermaniales**, the leafy liverworts, including *Porella*.

**Order 3.**—**Anthocerotales**, having the most complex sporophyte generations among liverworts, including *Anthoceros*, and *Megaceros*.

#### SUBDIVISION II.—MUSCI OR MOSSES

Plants found on the ground, on rocks, trees and in running water. Their life histories consist of two generations, gametophyte and sporophyte similar to the liverworts but differ from liverworts, generally, by the ever-present differentiation of the gametophyte body into distinct stem and simple leaves, and the formation of the sexual organs at the end of an axis of a shoot. They are either *monœcious*, when both kinds of sexual organs are borne on the same plant, or *diœcious*, in which case the antheridia and archegonia arise on different plants.

**Order I.—Sphagnales, or Bog Mosses, including the simple genus, *Sphagnum*.** Pale mosses of swampy habit whose upper extremities

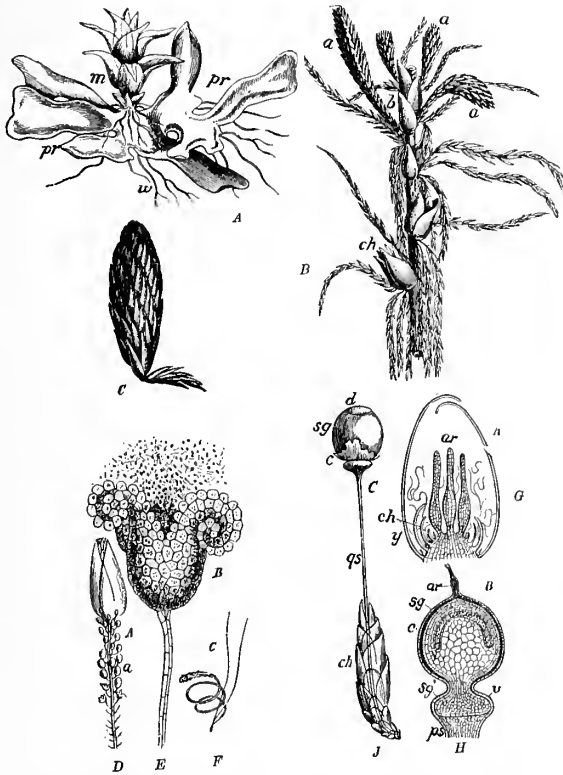


FIG. 109.—*Sphagnum acutifolium*, Ehrb. A, prothallus (*pr*), with a young leafy branch just developing from it; B, portion of a leafy plant; *a*, male cones; *ch*, female branches; C, male branch or cone, enlarged with a portion of the vegetative branch adhering to its base; D, the same, with a portion of the leaves removed so as to disclose the antheridia; E, antheridium discharging spores; F, a single sperm; G, longitudinal section of a female branch, showing the archegonia (*ar*); H, longitudinal section through a sporogonium; *sg*<sup>1</sup>, the foot; *ps*, pseudopodium; *c*, calyptra; *sg*, sporogonium, with dome of sporogenous tissue; *ar*, old neck of the archegonium; J, *Sphagnum squarrosum* Pers.; *d*, operculum; *c*, remains of calyptra; *qs*, mature pseudopodium; *ch*, perichætium. (Gager, from Schimper.)

repeat their growth periodically while their lower portions die away gradually and form peat, hence their frequent name of Peat Mosses.

**Order 2.—Andreæales**, including the single genus *Andreæa*, of xerophytic habit, occurring on siliceous rock.

**Order 3.—Bryales**, or true mosses, comprising the most highly

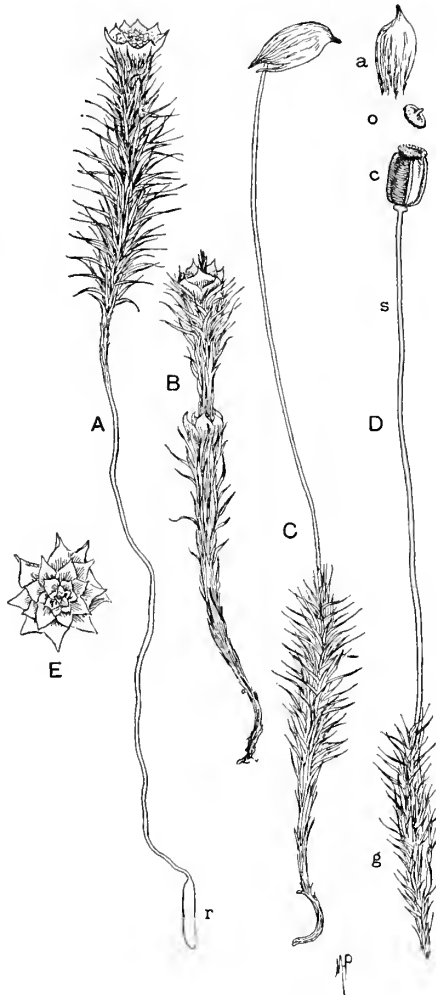


FIG. 110.—Hair-cap moss (*Polytrichum commune*). *A*, male plant; *B*, same, proliferating; *C*, female plant, bearing sporogonium; *D*, same; *g*, gametophyte; *s*, seta; *c*, capsule; *o*, operculum; *a*, calyptra; *E*, top view of male plant. (*Gager.*)

evolved type of bryophytes. Examples: *Polytrichum*, *Funaria*, *Hypnum*, and *Mnium*.

**Life History of *Polytrichum Commune* (A Typical True Moss).—**

*Polytrichum commune* is quite common in woods, forming a carpet-like covering on the ground beneath tall tree canopies. It is dioecious, the plants being of two kinds, male and female.

Beginning with a spore which has fallen to the damp soil, we note its beginning of growth (germination) as a green filamentous body called a *protonema*. This protonema soon becomes branched, giving



FIG. 111.—Protonemata of a moss bearing young gametophyte buds. (Gager.)

rise to hair-like outgrowths from its lower portion called *rhizoids* and *lateral buds* above these which grow into leafy stems commonly known as “moss plants.” At the tips of some of these leafy stems *antheridia* (male sexual organs) are formed while on others *archegonia* (female sexual organs) are formed. These organs are surrounded at the tips by delicate hairy processes called *paraphyses* as well as leaves for protection. The antheridia bear the antherozoids, the archegonia, the eggs or ova, as in the liverworts. When an abundance of moisture is present the antherozoids are liberated from the antheridia, swim through the water to an archegonium

and descend the neck canal, one fertilizing the egg by uniting with it. This completes the sexual or gametophyte generation. The fertilized egg now undergoes division until an elongated stalk bearing upon its summit a capsule is finally produced, this being known as the *sporogonium*. The base of the stalk remains imbedded in the basal portion of the archegonium, at the tip of the leafy stalk, and forms a *foot* or absorbing process. In growing upward the sporogonium ruptures the neck of the archegonium and carries it upward as the covering of the capsule, or *calyptra*. The calyptra is thrown off before the spores are matured within the capsule. The upper part of the capsule becomes converted into a lid or *operculum* at the margin of which an *annulus* or ring of cells forms. The cells of the annulus are hygroscopic and expand at maturity, throwing off the lid and allowing the *spores* to escape. This completes the asexual or sporophyte generation. The spores falling to the damp soil germinate into protonemata, thus completing the life cycle in which is seen an alteration of generations, the two phases, gametophyte alternating with sporophyte.

### DIVISION III.—PTERIDOPHYTA

The most highly developed cryptogams showing a distinct alternation of generations in their life history. They differ from the Bryophytes in presenting independent, leafy, vascular, root-bearing sporophytes.

#### SUBDIVISION I.—LYCOPODINEÆ OR CLUB MOSSES

Small perennial, vascular, dichotomously branched herbs with stems thickly covered with awl-shaped leaves. The earliest forms of vascular plants differing from ferns in being comparatively simple in structure, of small size, leaves sessile and usually possessing a single vein. Except in a few instances the sporangia are borne on leaves, crowded together and forming cones or spikes at the ends of the branches—Homosporous.

**Family I.—Lycopodiaceæ**, including the single genus *Lycopodium* with widely distributed species. The spores of *Lycopodium clavatum* are official.



**Family II.—Selaginellaceæ**, including the single genus *Selaginella*, with species for the greater part tropical. Plants similar in habit to the Lycopodiaceæ but showing heterospory.

**Family III.—Isoetaceæ**, including the single genus *Isoetes* whose species are plants with short and tuberous stems giving rise to a tuft of branching roots below and a thick rosette of long, stiff awl-shaped leaves above—Heterosporous.



FIG. 112.—*Lycopodium clavatum*. (Gager.)

#### SUBDIVISION II.—EQUISETINEÆ

(The Horsetails or Scouring Rushes)

The Equisetineæ, commonly known as the Horsetails or Scouring rushes, are perennial plants with hollow, cylindrical, jointed and fluted stems, sheath-like whorls of united leaves and terminal cone-like fructifications. Their bodies contain large amounts of silicon, hence the name scouring rushes.

In some varieties the fruiting cone is borne on the ordinary stem, in

others on a special stem of slightly different form. In the latter the spores are provided with elaters, which, being hygroscopic, coil and uncoil with increase or decrease in the amount of moisture present, thus aiding in the ejection of spores from the sporangia. The number of species is small and included under one genus, *Equisetum*.

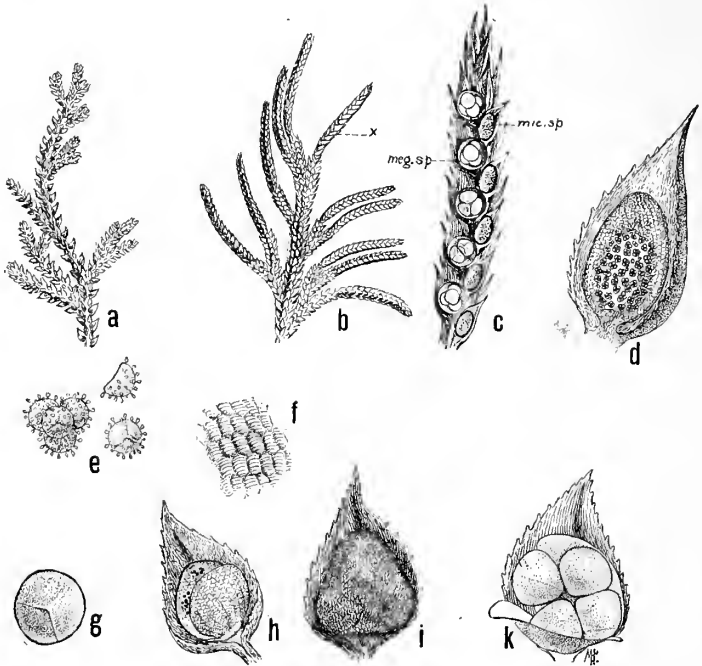


FIG. 113.—*Selaginella Martensii*. *a*, vegetative branch; *b*, portion of the stem, bearing cones (*x*); *c*, longitudinal section of a cone, showing microsporangia (*mic. sp.*) in the axils of microsporophylls, and megasporangia in the axils of megasporophylls; *d*, microsporangium with microsporophyll; *e*, microspores; *f*, portion of wall of sporangium, greatly magnified; *g*, megaspore; *h*, microsporangium opened, and most of the microspores scattered; *i*, megasporangium, with megasporophyll; *k*, same, opened, showing the four megaspores. (*Gager.*)

### SUBDIVISION III.—FILICINEÆ

The group Filicineæ is the largest among the vascular cryptogams and includes all the plants commonly known as Ferns. The main axis of a typical fern is a creeping underground stem or *rhizome*

which at its various nodes bears *rootlets* below and *fronds* above. These fronds are highly developed, each being provided with a petiole-like portion called a *stipe* which is extended into a *lamina* usually showing a forked venation. Some ferns possess laminæ

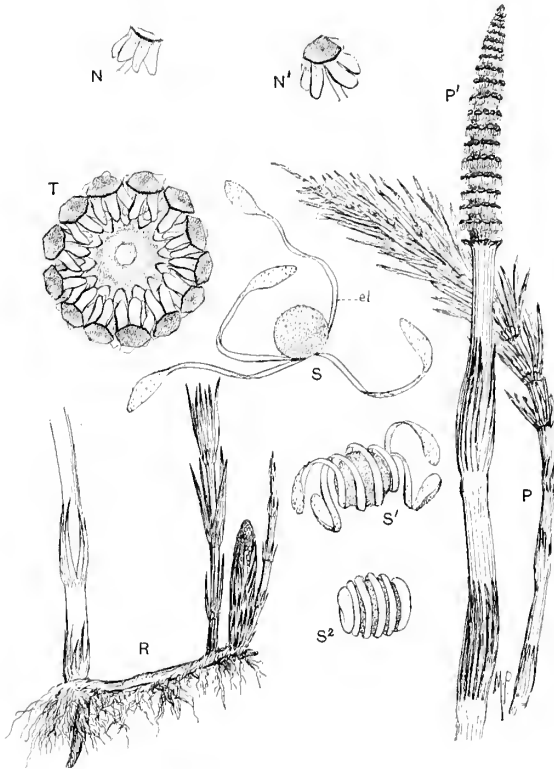


FIG. 114.—*Equisetum arvense*. P, sterile branch; P', fertile branch with strobilus, or cone; R, rhizome (underground); T, cross-section of cone, showing insertion of sporophylls in a whorl; N, N', sporophylls with pendant sporangia; S, S', S'', spores with coiled elaters (*el*). (Gager.)

which are lobed, each lobe being called a *pinna*. If a pinna be further divided, its divisions are called *pinnules*. The unfolding of a frond is circinate and it increases in length by apical growth. On the under surface of the laminæ, pinnæ, or pinnules may be seen

small brown patches each of which is called a *sorus*, and usually covered by a membrane called the *indusium*. Each sorus consists of a number of *sporangia* (spore cases) developed from epidermal cells. In some ferns the entire leaf becomes a spore-bearing organ (sporophyll). Most sporangia have a row of cells around the margin, the whole being called the *annulus*. Each cell of the annulus has a U-shaped thickened cell wall. Water is present within these cells and when it evaporates it pulls the cell walls together, straightening the ring and tearing open the weak side. The annulus then recoils

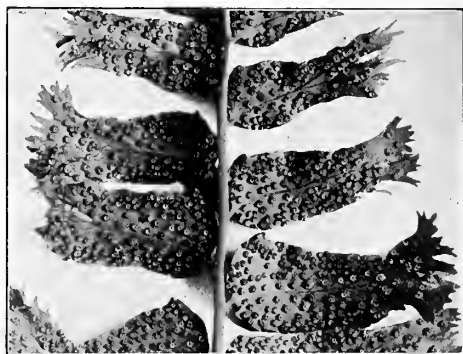


FIG. 115.—*Cyrtomium falcatum*. Under (dorsal) surface of a portion of a sporophyll, showing the numerous sori on the pinnæ. (Gager.)

and hurls the spores out of the sporangium. Upon coming into contact with damp earth each spore germinates, producing a green septate filament called a *protonema*. This later becomes a green heart-shaped body called a *prothallus*. It develops on its under surface *antheridia* or male organs and *archegonia* or female organs as well as numerous *rhizoids*. Within the antheridia are developed motile *sperms*, while *ova* are produced within the archegonia. The many ciliate sperms escape from the antheridia of one prothallus during a wet season, and, moving through the water, are drawn by a chemotactic influence to the archegonia of another prothallus, pass down the neck canals of these and fuse with the ova, fertilizing them. The fertilized egg or oöspore divides and redivides and soon becomes

differentiated into stem-bud, first leaf, root, and *foot*. The foot obtains nourishment from the prothallus until the root grows into the soil, when it atrophies, and the sporophyte becomes independent. Unequal growth and division of labor continue until a highly differentiated sporophyte results, the mature "fern plant."

#### ORDER 1.—FILICALES OR TRUE FERNS (HOMOSPOROUS)

*Family Polypodiaceæ*.—Sporangia with annulus vertical and incomplete.

The rhizomes and stipes of *Dryopteris filix-mas* and *Dryopteris marginalis* are official in the U. S. P. The fibro-vascular bundles of these are concentric in type but differ from the concentric fibro-vascular bundles of some monocotyledons in that xylem is innermost and phloem surrounds the xylem.

#### ORDER 2.—HYDROPTERALES OR WATER FERNS (HETEROSPOROUS)

*Family Salviniaceæ*. Floating ferns with broad floating leaves and submerged dissected leaves which bear sporocarps. Examples: *Salvinia* and *Azolla*.

#### DIVISION IV.—SPERMATOPHYTA (PHANEROGAMIA)

Plants producing real flowers and seeds. The highest evolved division of the vegetable kingdom.

#### SUBDIVISION I.—GYMNOSPERMÆ—THE GYMNASPERMS

The Gymnosperms comprise an ancient and historic group of seed plants which were more numerous in the Triassic and Carboniferous periods than now. They differ from the Angiosperms in several respects, viz.: they bear naked ovules on the edges or flat surfaces of leaves called carpels, while Angiosperms bear covered ones; each megaspore produces within itself a bulky prothallus, in the upper portion of which originate one or more archegonia, while in Angio-

sperms no recognizable prothallus has been proven to exist; the stored food tissue within their seeds is prothallial tissue loaded with starch, etc., while that in Angiosperm seeds (endosperm) is developed from the endosperm nucleus; the mode of growth of their stems is always indefinite while that of Angiosperms is either indefinite or definite.

The groups still extant are the Cycads or Fern Palms, the Gnetums, the Ephedras, the Ginkgos and the Conifers. Of these the Conifers comprising over 300 species are the most numerous. Many of them yield valuable products to pharmacy and the arts.



FIG. 116.—*Cyas revoluta*, showing terminal bud of foliage-leaves just opening. (Gager.)

The Conifers include the pines, spruces, hemlocks, cedars, firs, arbor vitæ, chamæcyparis, and larches. All of their number are evergreen except the larches, which drop their foliage upon the advent of winter.

**I. Order Coniferales.**—Trees with a single upright stem which develops side branches that spread out horizontally and taper to a point at the summit, giving the crown of the tree the appearance of a huge cone, rarely shrubs.

*Pinaceæ* (*Coniferae*) or *Pine Family*.—Trees or shrubs with resinous juice whose wood is characterized by being composed largely of tracheids with bordered pits. Leaves entire, awl- or needle-shaped frequently fascicled, exstipulate, usually evergreen. Flowers, monœcious or rarely diœcious, achlamydeous, in cones. Staminate cone of a large number of microsporophylls (stamens) closely packed together and arranged spirally around a central axis, each stamen bearing usually two pollen sacs. Carpellate cone composed of



FIG. 117.—Inflorescences of the pine. 1, Terminal twig; 2, ovulate cone; 3, staminate cone; 4, two-year-old cone. (Hamaker.)

spirally arranged scales, each of which bears a pair of naked ovules (megaspores) near the base of its upper face, or, ovules springing from a cupuliform disc. Fruit a cone with woody or fleshy scales (*Pinus*, *Thuja*, *Abies*, *Picea*, etc.), a galbulus (*Juniiperus*) or a drupe composed of the thickened and fleshy disc surrounding an erect seed (*Taxus*). Seeds albuminous. Embryo with two or more cotyledons.

Official drug	Part used	Botanical origin	Habitat
Terebinthina N.F.	Concrete oleoresin	<i>Pinus palustris</i> and other species of <i>Pinus</i>	Southern United States
Resina	Resin	<i>Pinus palustris</i> and other species of <i>Pinus</i>	Southern United States
Oleum Tere- binthinae	Volatile oil	<i>Pinus palustris</i> and other species of <i>Pinus</i>	Southern United States
Pix Liquida	Product of de- structive distilla- tion	<i>Pinus palustris</i> and other species of <i>Pinus</i>	Southern United States
<i>Pinus Alba</i> N.F.	Inner bark	<i>Pinus Strobus</i>	United States and Canada
Oleum Pini Pumi- lionis	Volatile oil	<i>Pinus montana</i>	Tyrolese Alps
Terebinthina <i>Laricis</i> N.F.	Oleoresin	<i>Larix europæa</i>	Alps and Carpathians
<i>Juniperus</i> N.F.	Fruit	<i>Juniperus</i> <i>communis</i>	} North America, Europe and Asia
Oleum Juniperi	Volatile oil	<i>Juniperus</i> <i>communis</i>	
Oleum Cadinum <i>Thuja</i> N.F.	Empyreumatic oil Leafy young twigs	<i>Juniperus Oxycedrus</i> <i>Thuja occidentalis</i>	United States and Canada
Oil of Cedarwood	Oil from wood	<i>Juniperus</i> <i>Virginiana</i>	North America
<b>Unofficial drug</b>			
<i>Sabina</i>	Tops	<i>Juniperus Sabina</i>	Europe
<i>Pix Burgundica</i>	Resinous exudate	<i>Abies excelsa</i>	Europe and Asia
Terebinthina <i>Canadensis</i>	Liquid oleoresin	<i>Abies balsamea</i>	Northern United States and Canada
<i>Sandaraca</i>	Resinous exudate	<i>Callitris</i> <i>quadri-valvis</i>	Africa
Dammar	Resinous exudate	<i>Agathis</i> <i>loranthifolia</i>	
<i>Succinum</i> (Amber)	Fossil resin	<i>Pinites succinifer</i>	Basin of Baltic
Bordeaux Turpentine	Concrete oleoresin	<i>Pinus maritima</i>	France
<i>Pix Canadensis</i>	Oleoresin	<i>Tsuga canadensis</i>	North America
Oregon Balsam	Oleoresin	<i>Pseudotsuga</i> <i>mucronata</i>	Western United States and British Columbia
Spruce Gum	Gum	<i>Picea canadensis</i> <i>Picea mariana</i> <i>Picea rubra</i>	} Canada and New England



## SUBDIVISION II.—ANGIOSPERMÆ OR ANGIOSPERMS

(Plants with covered seeds)

## CLASS A.—MONOCOTYLEDONEÆ

A class of Angiosperms characterized by the following peculiarities:

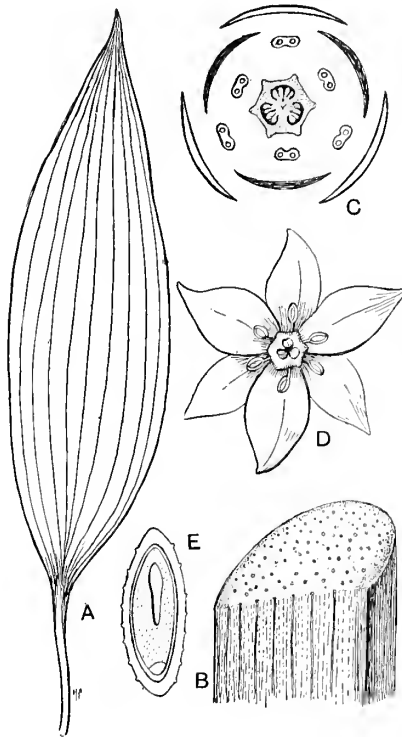


FIG. 118.—Morphology of the typical monocotyledonous plant. *A*, leaf, parallel-veined; *B*, portion of stem, showing irregular distribution of vascular bundles; *C*, ground plan of flower (the parts in 3's); *D*, top view of flower; *E*, seed, showing monocotyledonous embryo. (*Gager.*)

One cotyledon or seed leaf in the embryo.

Stems endogenous with closed collateral or concentric fibro-vascular bundles, which are scattered.

Leaves generally parallel veined.

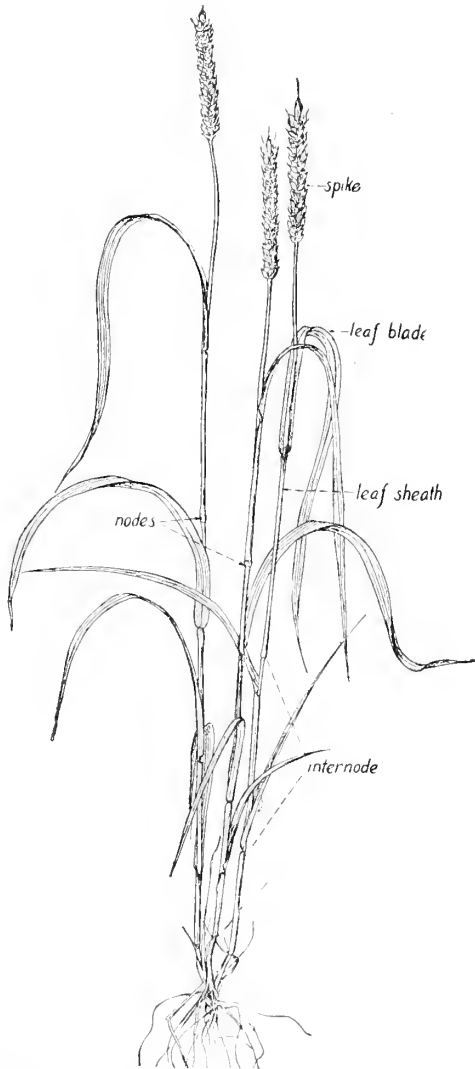


FIG. 119.—Wheat plant showing the general habit of grasses. (Robbins.)

Flowers trimerous (having the parts of each whorl in threes or multiple thereof).

Secondary growth in roots generally absent.

Medullary rays generally absent.



FIG. 120.—Pistillate and staminate inflorescences of corn (*Zea mays*).  
(Robbins.)

I. **Order Graminales.**—*Graminaceæ* or *Grass Family.*—Mostly herbs with cylindric, hollow jointed stems whose nodes are swollen. The leaves are alternate, with long split sheaths and a ligule.

Flowers generally hermaphroditic and borne in spikelets making up a spicate inflorescence. Lowest floral leaves of each spikelet are called glumes, which are empty and paired. Fruit, a caryopsis or grain. Embryo with scutellum. Seeds, albuminous. Seed coat fused with fruit coat to form one layer.

Official drug	Part used	Botanical name	Habitat
Triticum	Rhizome and roots	Agropyron repens	Europe and Asia
Saccharum	Refined sugar	Saccharum officinarum	Tropics
		Beta vulgaris var. Rapa	Germany
		and Sorghum sp.?	Asia and Africa
Maltum	Seed, partially germinated and dried	Hordeum sativum	Asia
Amylum	Starch	Zea Mays	Mexico
Zea N.F.	Styles and stigmas	Zea Mays	Mexico

II. **Order Principes.**—*Palmaceæ* or *Palm Family*.—Tropical or subtropical shrubs, rarely trees, having unbranched trunks which are terminated by a crown of leaves, in the axils of which the flowers are produced. The leaves are well developed with pinnate or palmate blades and a fibrous sheathed clasping petiole. Inflorescence, a lateral spathe with small regular flowers. Fruit, either a nut, with leathery epicarp, fibrous or cellular mesocarp and thin membranous endocarp, or a drupe (Cocoanut) with leathery epicarp, broadly fibrous mesocarp and stony endocarp, or a berry as in the Date Palm, *Phoenix*, with membranous epicarp, succulent mesocarp and soft succulent endocarp. Seeds, solitary.

Official drug	Part used	Botanical name	Habitat
Sabal	Fruit (drupe)	Serenoa serrulata	South Carolina to Florida
<b>Unofficial</b>			
Dragon's Blood	Inspissated juice	Calamus Draco	East Indies
Cocoanut oil	Fixed oil	Cocos nucifera	Tropics
Carnauba wax	Wax from leaves	Copernicia cerifera	Brazil
Areca nut	Seed	Areca Catechu	Asia and East Indies <sup>1</sup>
Palm oil	Fixed oil	Elæis guineensis	West Africa



FIG. 121.—Sabal palmetto. This palm, which appears in the center of the figure, yields the official drug, sabal. In the right distance a barragona palm. Cuba. (Gager.)

III. Order *Arales*.—*Araceæ* or *Arum* Family.—Perennial herbs with fleshy rhizomes or corms, and long petioled leaves, containing an acrid or pungent juice. Flowers crowded on a spadix, which is usually surrounded by a spathe. Fruit a berry. Seeds with large fleshy embryo.

Unofficial drug	Part used	Botanical name	Habitat
Calamus	Unpeeled rhizome	<i>Acorus calamus</i>	Europe, Asia, North America
Skunk cabbage	Rhizome	<i>Symplocarpus foetidus</i>	North America
Indian turnip	Corm	<i>Arisæma triphillum</i>	North America

IV. Order *Liliales*.—*Liliacæ* or *Lily* Family.—Herbs (*Lilum*), shrubs (*Yucca*), or trees (*Dracena Draco*), with regular and sym-

metrical almost always six-anded flowers. Stem either short creeping underground (*Polygonatum*) or swelling up and forming bulbs (Hyacinth), or corms (*Colchicum*), or stem may elongate above ground and become wiry and herbaceous or semi-shrubby as *Smilax*,



FIG. 122.—*Acorus calamus*. (Sayre.)

or the stem may remain short giving rise to thick fleshy and saporiferous leaves as in *Aloe*. Leaves linear to lanceolate, ovate, rarely wider, divisible into sheathing base, narrow petiole and expanded blade. Venation, parallel becoming in some ovate leaves parallel

with oblique connections, reticulate or highly reticulate as in *Smilax*, etc. The perianth is parted into six segments, the calyx and corolla being alike in color. Anthers introrse. Ovary three-locular with a

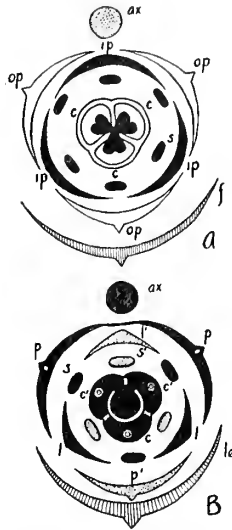


FIG. 123.—Diagram of *A*, lily flower, and *B*, grass flower, showing homologous structures. *A*, *f*, bract; *ax*, axis; *op*, outer perianth; *ip*, inner perianth; *s*, stamens; (*c*) tricarpellary ovary. *B*, shaded structures are aborted; *le*, lemma (bract); *ax*, axis; *p* and *p'*, palet (outer perianth); *l* and *l'*, lodicules (inner perianth); *s* and *s'*, two whorls of stamens; *c*, tricarpellary ovary. (*A*, *Robbins*. *B*, after *Shuster*.)

single style. Fruit a three-locular, loculicidally dehiscent capsule (*Lilium*, etc.) or rarely a berry (*Asparagus*, etc.). Seeds usually numerous, albuminous.

Official drug	Part used	Botanical name	Habitat
Sarsaparilla	Root	<i>Smilax medica</i>	Mexico
		<i>Smilax ornata</i>	Costa Rica
		<i>Smilax officinalis</i>	Guatemala, Honduras and Nicaragua
Veratrum	Rhizome and roots	<i>Veratrum viride</i>	United States
Colchici Cormus	Corm	<i>Colchicum autumnale</i>	Mediterranean Basin

Official drug	Part used	Botanical name	Habitat
Colchici Semen	Seed	Colchicum autumnale	Mediterranean Basin
Aloe	Inspissated juice of leaves	{ Aloe vera Aloe Perryi	{ Dutch West Indies Socotra and East Africa
Scilla	Bulb	{ Aloe ferox Urginea maritima	{ South Africa Mediterranean Basin
Veratrina	Mixture of alkaloids	Asagraea officinalis	Mexico and Central America
Convallariæ Radix N.F.	Rhizome and roots	{ Convallaria majalis	{ Europe, Asia, United States
Convallariæ Flores N.F.	Inflorescence		
Trillium N.F.	Rhizome and roots	Trillium erectum	North America
Allium N.F.	Bulb (fresh)	Allium sativum	Europe, Asia, North America
Aletris N.F.	Rhizome and roots	Aletris farinosa	Eastern United States
Helonias N.F.	Rhizome and roots	Chamælorium luteum	Eastern United States

*Dioscoreaceæ or Yam Family.*—Herbs or shrubs with twining stems arising from large tuberous roots or knotted rootstocks. Leaves ribbed and netted-veined. Flowers small, dioecious, regular, having a six-cleft calyx-like perianth, six stamens and a three-celled ovary. Fruit usually a membranous three-angled or winged capsule.

Unofficial drug	Part used	Botanical name	Habitat
Dioscorea	Rhizome	Dioscorea villosa	United States

*Iridaceæ or Iris Family.*—Perennial herbs with equitant two-ranked leaves and regular or irregular flowers which are showy. Fruit a three-celled, loculicidal, many-seeded capsule. Rootstocks, tubers, or corms mostly acid.

Official drug	Part used	Botanical name	Habitat
Iris N.F.	Peeled rhizome	{ Iris florentina Iris pallida Iris germanica	{ Europe
Iris Versicolor N.F.	Rhizome	Iris versicolor	Eastern United States
Crocus N.F.	Stigmas	Crocus sativus	Mediterranean Basin



V. Order Scitiminiales.—*Zingiberaceæ* or *Ginger Family*.—Tropical plants, perennial herbs, with fleshy rhizomes and large elliptical



FIG. 124.—*Smilax officinalis*—Portion of vine and rhizome. (Sayre.)

pinnately-veined leaves. The leaf sheaths are folded tightly around each other so as to give the appearance of a stem. Flowers, very

irregular, trimerous; sepals three short, often green; petals three, elongate, often fused below; stamens three to four abortive, petaloid, one often absent, a sixth alone fertile and stamen-like. The petaloid

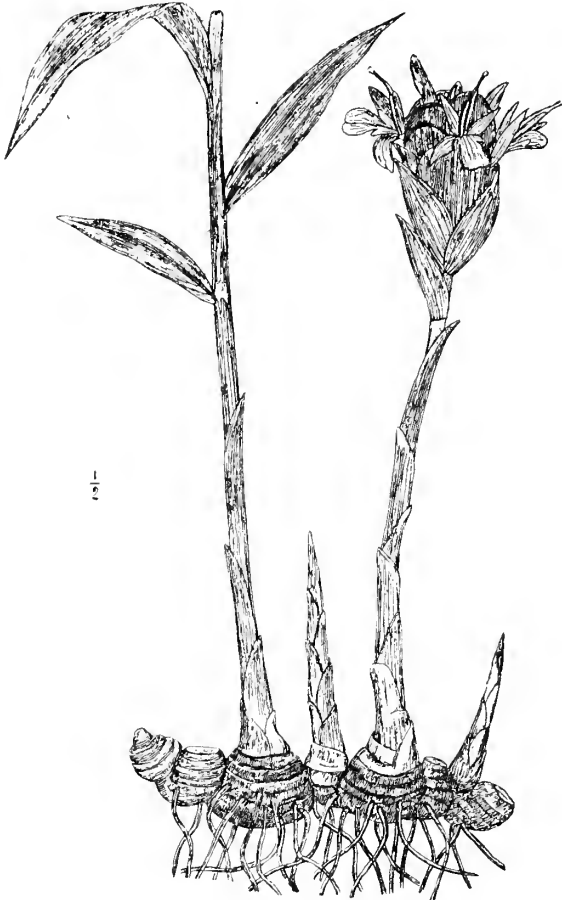


FIG. 125.—*Zingiber officinale*. (Sayre.)

stamens constitute the most attractive parts of the flower. Pistil, inferior, tricarpeillary. Fruit, a capsule. Seeds, albuminous with both perispermic and endospermic albumen.

Official drug	Part used	Botanical name	Habitat
Zingiber	Rhizome	<i>Zingiber officinale</i>	Asia
Cardamomi Semen	Seeds	<i>Elettaria</i> <i>Cardamomum</i>	Indo-China
Galanga N.F.	Rhizome	<i>Alpinia</i> <i>officinarum</i>	Asia
Zedoaria N.F.	Rhizome	<i>Curcuma Zedoaria</i>	Asia, Madagascar
<b>Unofficial drug</b>			
Curcuma	Prepared rhizome	<i>Curcuma longa</i>	South Asia

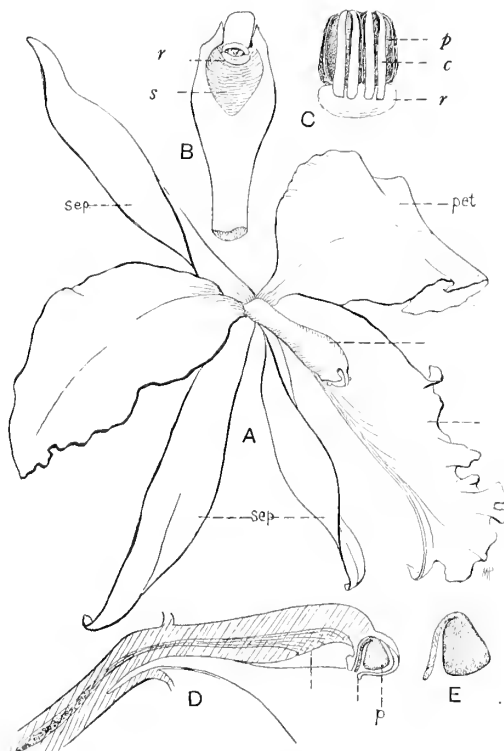


FIG. 126.—Floral organs of an orchid (*Cattleya* sp.). A, the entire flower; *sep.*, sepal; *pet.*, petal; B, column, showing *s*, stigma and *r*, the rostellum (beak), with the small glands at the tip; to the glands are attached the four strap-shaped caudicles of the pollinia; C, pollinia, with the four caudicles; below, the gland; D, longitudinal section of the column; *p*, pollinium; E, the same, enlarged. (Gager.)

VI. **Order Orchidales.**—*Orchidaceæ* or *Orchid Family.*—Perennial herbs of terrestrial or terrestrial saprophytic or epiphytic growth, having grotesque flowers. Roots fibrous or tuberous often saprophytic in relation, or aerial and with velamen. Stems and branches upright, in epiphytic types often forming pseudobulbs. Leaves alternate, entire, parallel-veined, sheathing at base, rarely reduced to yellowish or pale scales in saprophytes. Flowers irregular, usually attractive, entomophilous, arranged in elongated spikes or racemes, trimerous. Sepals, three usually similar; petals three of

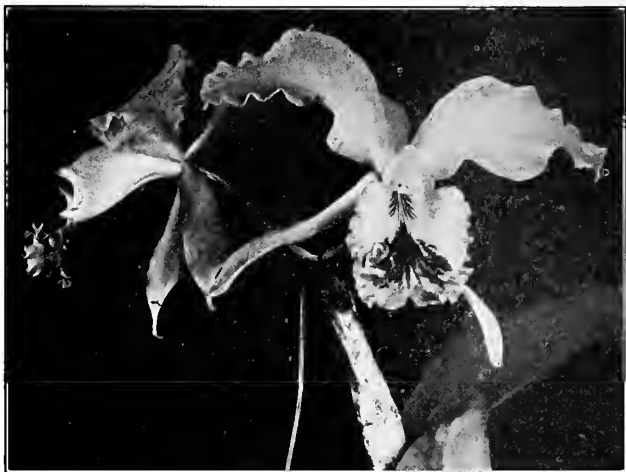


FIG. 127.—Flower of an orchid (*Cattleya* sp.). (Gager.)

which two often resemble sepals, third is variously, often greatly modified and fused with two outer petaloid stamens as a labellum or lighting-board for insects. Third stamen of outer whorl fertile (*Orchideæ*) or a barren knob (*Cypripediæ*); pollen of fertile anther agglutinate as pollinia. Three stamens of inner circle barren and petaloid or one absent (*Cypripediæ*). Stamens all epigynous and often three are fused with the style as gynandrium. Carpels three, syncarpous, with inferior, three rarely four, one (usually)-celled ovary. Fruit a capsule, three-valved and one-celled. Seeds minute, abundant and wind disseminated.

Official drug	Part used	Botanical name	Habitat
Vanilla N.F.	Fruit	<i>Vanilla planifolia</i>	Mexico
Cypripedium N.F.	Rhizome and roots	<i>Cypripedium hirsutum</i> <i>Cypripedium parviflorum</i>	United States



FIG. 128.—*Vanilla planifolia*—Branch showing leaf and flowers. (Sayer.)

#### CLASS B.—DICOTYLEDONEÆ

Plants having the following characteristics:  
 Two-seed leaves (cotyledons) in embryo.  
 Netted-veined leaves.

Stems, and roots of secondary growth with open collateral fibrovascular bundles, radially arranged about pith.

Exogenous stems.

Medullary rays present.

Cambium.

Roots developing secondary structure.

Flowers tetra- or pentamerous (parts of each whorl, four or five or multiple thereof).

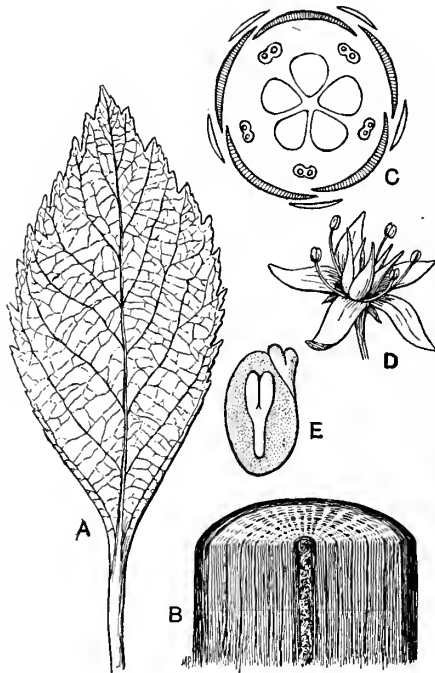


FIG. 129.—Morphology of a typical dicotyledonous plant. *A*, leaf, pinnately-netted veined; *B*, portion of stem, showing concentric layers of wood; *C*, ground-plan of flower (the parts in 5's); *D*, perspective of flower; *E*, longitudinal section of seed, showing dicotyledonous embryo. (*Gager.*)

SUB-CLASS A.—ARCHICHLAMYDEÆ

Those dicotyledonous plants in which the petals are distinct and separate from one another or are entirely wanting. That group of

the Archichlamydeæ whose flowers show the absence of petals and frequently of sepals is called the Apetalæ. The group whose plants have flowers showing the parts of their corolla (petals) separate and distinct is called the Choripetalæ.



FIG. 130.—*Piper cubeba*—Fructing branch and fruit (enlarged). (Sayre.)

**I. Order Piperales.**—*Piperaceæ* or *Pepper Family*.—A family of aromatic herbs and shrubs with jointed stems, opposite, verticillate, or sometimes alternate leaves without stipules, and spiked inconspicuous, wind-pollinated flowers. The characteristic fruit is a berry

enclosing a single upright seed with abundant perisperm (from megasporangial tissue) and reduced endosperm (from matured embryo sac).

Official drug	Part used	Botanical name	Habitat
Cubeba	Unripe fruit	<i>Piper Cubeba</i>	Borneo, Java, Sumatra
Piper	Unripe fruit	<i>Piper nigrum</i>	Cochin-China, India
Kava N.F.	Rhizome and roots	<i>Piper methysticum</i>	South Sea Islands
Matico N.F.	Leaves	<i>Piper angustifolium</i>	Peru, Bolivia



FIG. 131.—Willow (*Salix*). Leafy branch, bearing two pistillate catkins. Staminate flower above, at the left; pistillate flower below, at the right. (Gager, after Britton and Brown.)

II. Order Salicales.—*Salicaceæ* or Willow Family.—Shrubs or trees of temperate or cold regions, with upright woody stems. Bark often containing bitter principles (Salicin etc.).

Leaves alternate, simple, entire, stipulate; stipules rarely green, persistent, usually functioning as winter bud-scales and falling in spring.



Inflorescences diœcious spikes, so on separate plants. Staminate spikes forming deciduous catkins of yellowish flowers, pistillate as persistent spikes of green flowers, at length maturing fruit.

Flowers of catkins numerous, each of two to five (Willow) or six to fifteen (Poplar) stamens in axil of a small bract leaf, sometimes with small nectar knob or girdle at base; pollen abundant, hence plants anemophilous, rarely entomophilous. Pistillate flowers green, each of a bicarpellate pistil in axil of bract, ovary one-celled with parietal placentation, style simple, stigma bilobed.

Fruit a capsule dehiscent longitudinally. Seeds small, exalbuminous, surrounded by a tuft of hairs for dissemination.

Official drug	Part used	Botanical name	Habitat
Salicin	Glucoside	Several species of Salix and Populus	Europe, North America
Salix	Bark	Salix alba	Europe
Populi Gemmæ N.F.	Closed leaf buds	{ Populus nigra Populus balsamifera }	North America

**III. Order Myricales.**—*Myricaceæ* or *Bayberry Family*.—Diœcious or sometimes monœcious, aromatic shrubs or trees with watery juice and possessing underground branches which arch downward then upward producing many suckers. Roots fibrous and bearing many short rootlets upon which are frequently found coralloid clusters of tubercles containing the *Actinomyces Myricarum* Youngken. Leaves alternate, revolute in vernation, serrate, irregularly dentate, lobed or entire, rarely pinnatifid, pinnately and reticulately veined, pellucid punctate, evergreen or deciduous, generally exstipulate, rarely stipulate. Flowers naked, unisexual, monœcious or diœcious, in the axils of unisexual or androgynous aments from scaly buds formed in the summer in the axils of the leaves of the year, remaining covered during the winter and opening in March or April before or with the unfolding of the leaves of the year.

Staminate flowers in elongated catkins, each consisting of two to eight stamens inserted on the torus-like base of the oval to oval-lanceolate bracts of the catkin, usually subtended by two or four or rarely by numerous bracteoles; filaments short or elongated,

filiform, free or connate at the base into a short stipe; anthers ovoid, erect, two-celled, extrorse, showing longitudinal dehiscence. Pistillate flowers in ovoid or ovoid-globular catkins. Gynæcium of two united carpels on a bract. Ovary sessile, unicellular, sub-



FIG. 132.—Two *Myrica cerifera* trees growing in a field near a brackish swamp at Rio Grande, N. J. Photographed by author July 26, 1914.

tended by two lateral bracteoles which persist under the fruit, or by eight linear subulate bracteoles, accrescent, and forming a lacinate involucre inclosing the fruit; styles short and dividing into two elongated style arms which bear stigmatic surfaces on their inner face; ovule orthotropous, solitary with a basilar placenta and

superior micropyle. Fruit an akene or ceriferous nut. Pericarp covered with glandular emergences which secrete wax or fleshy emergences, smooth and lustrous or smooth, glandular. Seed



FIG. 133.—Fructiferous branches of *Myrica Caroliniensis* (to left) and *Myrica cerifera* (to right) as they appear in early winter. The former species is deciduous, while the latter is evergreen. Collected by author at Wildwood, N. J., Dec. 16, 1914.

erect, exalbuminous, covered with a thin testa. Embryo straight, cotyledons thick, plano-convex; radicle short, superior.

There are two distinct genera of this family, e.g., *Myrica* and *Comptonia*.

Official drug  
Myrica N.F.

Part used  
Bark of root

Botanical name  
*Myrica cerifera*

Habitat  
Eastern United  
States



FIG. 134.—Fructiferous branch of *Myrica Gale*, showing mature pistillate catkins and nature of leaves. Collected at the south end of Peak's Island in Casco Bay, Maine, September, 1913.

IV. Order Juglandales.—JUGLANDACEÆ.—A family of apetalous exogenous trees—the walnut family—with alternate odd-pinnate leaves and monœcious flowers, the sterile in catkins, the fertile solitary or in a small cluster or spike. The fruit is a dry drupe with

a bony nut-shell and a four-lobed seed. It embraces five genera, of which *Carya* (*Hicoria*) and *Juglans* are represented in the United States, and about 35 species.

Official drug	Part used	Botanical name	Habitat
Juglans N. F.	Inner root bark	Juglans cinerea	United States

*Betulaceæ* or *Birch Family*.—A family of aromatic trees or shrubs distinguished by monœcious flowers with scaly bracts and astringent resinous bark. Differs from *Fagaceæ* by superior ovary and absence of cupule. To this family belong the hazelnuts, birches, alders, the ironwood, and the hornbean.

Official drug	Part used	Botanical name	Habitat
(Oleum Betulæ)	Volatile oil	Betula lenta	North America
Methylis salicylas			

**V. Order Fagales.**—*Fagaceæ* or *Beech Family* (*Cupuliferæ*).—Apetalous trees or shrubs having alternate pinnately-veined leaves, monœcious flowers, the male in drooping aments, the female solitary, clustered, or in scaly catkins. Fruit a one-celled one-seeded nut. The beech, oak and chestnut are the principal genera.

Official drug	Part used	Botanical name	Habitat
Galla	Excrescence	Quercus infectoria	Europe
Castanea N.F.	Leaves	Castanea dentata	North America
Quercus N.F.	Bark	Quercus alba	North America

The cork of commerce is obtained from the bark of *Quercus Suber* and *Quercus occidentalis*, plants indigenous to Spain and France.

**VI. Order Urticales.**—*Ulmaceæ* or *Elm Family*.—Forest trees indigenous to the temperate and tropical zones, characterized by being woody plants, with pinnately veined leaves and caducous stipules and without milky juice. Their flowers are unisexual or hermaphroditic with six or four parts to the perianth. Fruit a samara.

Official drug	Part used	Botanical name	Habitat
Ulmus	Inner bark	Ulmus fulva	United States and Canada

*Moraceæ* or *Mulberry Family*.—Mostly shrubs or trees, rarely herbs, perennials, many of them containing a milky juice, with



FIG. 135.—*Quercus infectoria*—Branch and nutgall. (Sayre.)

small axillary, clustered or solitary unisexual flowers, variously colored; leaves ovate with serrate margin and having caducous stipules; fruit an akene enclosed by the perianth.

Official drug	Part used	Botanical name	Habitat
Cannabis	Flowering tops of pistillate plant	<i>Cannabis sativa</i>	Asia
		<i>Cannabis sativa</i>	
		<i>var. indica</i>	
Ficus N.F.	Fruit	<i>Ficus Carica</i>	Persia
Humulus	Strobile	<i>Humulus lupulus</i>	Europe, Asia, North America
Lupulinum N.F.	Glandular trichome	<i>Humulus lupulus</i>	

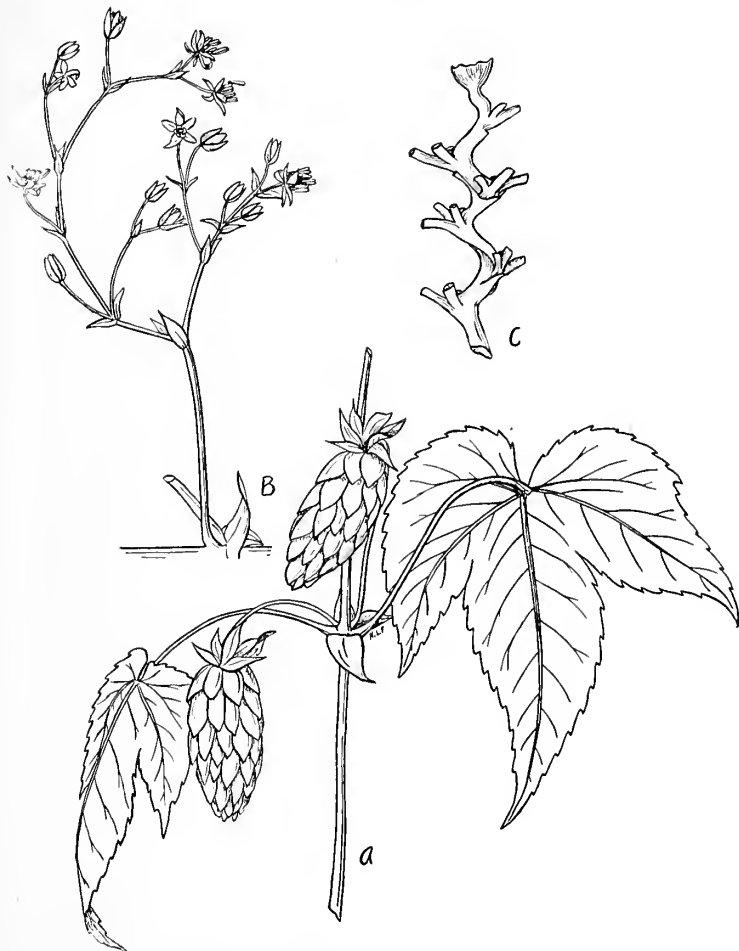


FIG. 136.—Hop (*Humulus lupulus*). A, portion of plant showing pistillate inflorescences; B, staminate inflorescence; C, rachis of pistillate inflorescence ("hop"). (Robbins.)

VII. Order Santalales.—*Santalaceæ* or *Sandalwood Family*.—Herbs, shrubs or trees having entire exstipulate leaves, greenish flowers and oily seeds. Many are parasitic on the roots of other plants.

Official drug	Part used	Botanical name	Habitat
Oleum Santali	Volatile oil	} Santalum album	{ India and East Indies
Santalum Album N.F.	Heartwood		

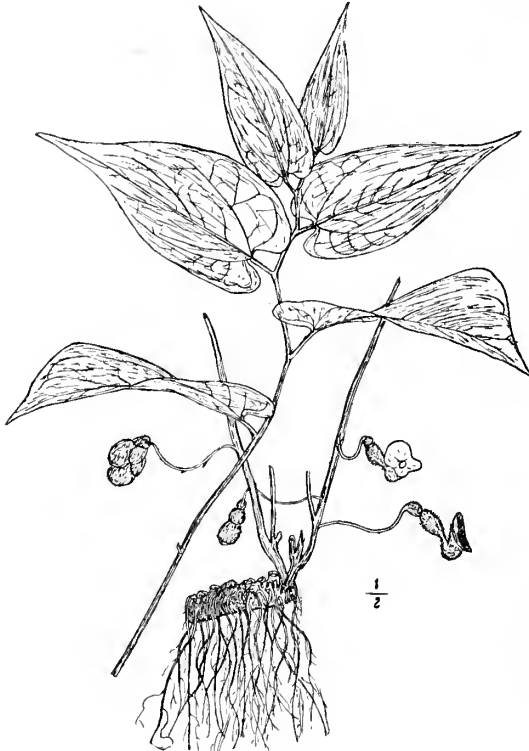


FIG. 137.—*Aristolochia serpentaria*. (Sayre.)

VIII. Order Aristolochiales.—*Aristolochiaceæ* or *Birthwort Family*.—Herbs or twining semi-woody or woody plants, having more or less swollen nodes from which spring cordate or reniform or ovate leaves. Flowers regular (*Asarum*, etc.) or irregular (*Aristolochia*) often



offensively smelling. Fruit a capsule. Seeds with copious albumen and minute embryo.

Official drug	Part used	Botanical name	Habitat
Serpentaria	Rhizome and roots	<div style="display: flex; align-items: center;"> <div style="font-size: 2em; margin-right: 5px;">}</div> <div style="text-align: left;"> <p>Aristolochia Serpentaria Aristolochia reticulata</p> </div> </div>	United States
Asarum N.F.	Rhizome and roots	Asarum canadensis	United States

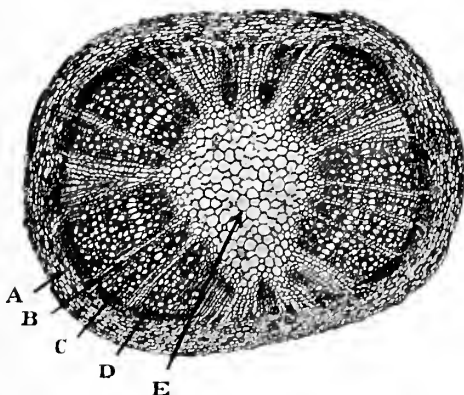


FIG. 138.—*Serpentaria*—Cross-section of rhizome. (25 diam.) A, parenchyma of cortex; B, Medullary ray; C, xylem; D, phloem; E, medulla. (Sayre.)

**IX. Order Polygonales.**—*Polygonaceæ* Family.—Usually herbs (*Polygonum*, *Rumex*, etc.) rarely trees (*Coccoloba uvifera* and *C. platyclada*) or shrubs (*Muhlenbeckia*, *Brunnichia*) having strong vertical tap roots and spreading secondary roots more or less provided with tannin compounds. Stems elongate, green, to woody, rarely flattened, leathery, phylloidal (*Muhlenbeckia platyclada*) still more rarely tendriform (*Antigonum leptopus*). Leaves alternate rarely opposite or whorled (*Eriogonum*), entire, rarely lobed (*Rheum palmatum*, *Rumex acetosella*), petiolate, rarely sessile, and stipulate. Stipules fused and forming a greenish membranous upgrowth (*ocrea*) which sheathes the stem. Inflorescence racemose with many dense scorpioid or helicoid cymes, which in some forms condense into single flowers. Flowers regular, pentamerous, with simple calyx becoming trimerous with two whorls of three

sepals each. Stamens varying from fifteen or twelve to nine or six more rarely to five, four, three to one (*Kœnigia*), hypogynous, more rarely by enlargement of receptacle and slight fusion of sepals, perigynous. Pistil tri- to bicarpellate often three- to two-sided, ovary one-celled with one ovule. Styles three, rarely two, radiating penicillate in wind-pollinated inconspicuous flowers becoming condensed knob-like in conspicuous insect-pollinated flowers. Fruit a triangular or biconvex akene often crowned by persistent styles and surrounded by persistent closely applied sepals. Seeds solitary, albuminous, with straight embryo, or in *Rumex*, curved embryo.

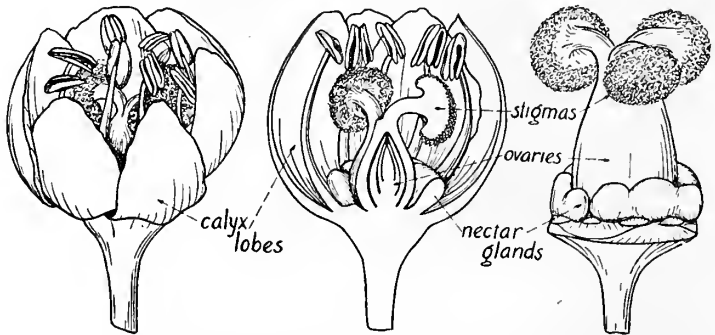


FIG. 139.—Rhubarb (*Rheum*) flower, external view, median lengthwise section, and with perianth and stamens removed. (*Robbins, after Lürssen.*)

Official drug	Part used	Botanical name	Habitat
Rheum	Rhizome	Rheum officinale	China and Thibet
		Rheum palmatum and the variety tanguticum and probably other species	
Rumex N.F.	Root	Rumex crispus	Europe
		Rumex obtusifolius	
<b>Unofficial</b>			
Bistorta	Rhizome	Polygonum Bistorta	Europe and Asia

**X. Order Chenopodiales** (*Centrospermæ*).—*Chenopodiaceæ* or *Goosefoot Family*.—Usually herbaceous halophytes or shore growers,

growing also in any alkaline soil, more rarely shrubs (*Atriplex*) or low trees (*Haloxylon*).

Among them are several garden vegetables (*Spinach*, *Beets*, *Mangels*) and a number of weeds. Leaves alternate to opposite



FIG. 140.—*Phytolacca decandra* (in foreground), growing in damp woodland.

sometimes reduced to teeth, entire or lobed. Inflorescence spikes or short racemes of condensed cymes. Flowers regular, usually small and greenish. They are either perfect (*Beta*), monœcious (*Chenopodium*), diœcious (*Atriplex* sp.), or polygamous (*Kochia*) Fruit a utricle. Seed albuminous.

Official drug	Part used	Botanical name	Habitat
Oleum Chenopodii	Volatile oil	Chenopodium anthelminticum	United States
Saccharum	Refined sugar	Beta vulgaris	Europe
<b>Unofficial</b> Chenopodium	Fruit	Chenopodium anthelminticum	United States

*Phytolaccaceæ*.—A family of apetalous trees, shrubs, or woody herbs—the pokeweed family—with alternate entire leaves, and flowers resembling those of the goosefoot family (*Chenopodiaceæ*), but differing in having the several-celled ovary composed of carpels united in a ring, and forming a berry in fruit. It embraces 21 genera, and 55 species, tropical and sub-tropical.

Official drug	Part used	Botanical name	Habitat
Phytolacca N.F.	Root	Phytolacca decandra	North America

XI. **Order Ranales.**—*Magnoliaceæ* or *Magnolia Family*.—Trees and shrubs having alternate leaves and single large flowers with calyx and corolla colored alike. Sepals and petals deciduous, anthers adnate. Carpels and stamens numerous. Bark aromatic and bitter. Fruit a collection of follicles dehiscent dorsally.

Official drug	Part used	Botanical name	Habitat
Oleum anisi	Volatile oil	Illicium verum	South China
<b>Unofficial</b> Winter's Bark	Bark	Drimys Winteri	South America

*Ranunculaceæ* or *Buttercup Family*.—Herbs, rarely shrubs (*Clematis*) with acrid, poisonous, watery juices and with alternate, rarely opposite, simple, rarely compound, exstipulate leaves. Flowers pentamerous, regular to irregular, incomplete to complete, aposepalous and apopetalous. Sepals five—rarely more or less—green to petaloid, regular, passing to irregular (Larkspur, Monkshood). Petals none or five, regular to rarely irregular, often nectariferous and with nectariferous petals often variously transformed. Stamens indefinite, hypogynous. Pistil of many to few apocarpous carpels, each carpel with one to several ovules. Fruit a collection of

achenes (*Ranunculus*, *Anemonella*), or a collection of follicles (Columbine, Larkspur, Peony) or rarely a berry as in Baneberry (*Actæa*). Seeds albuminous.



FIG. 141.—Above ground portion of *Aconitum* showing palmately-divided leaves and hooded flowers.

Official drug	Part used	Botanical name	Habitat
Hydrastis	Rhizome and roots	<i>Hydrastis canadensis</i>	Eastern United States and Canada
<i>Aconitum</i>	Tuberous root	<i>Aconitum</i> <i>Napellus</i>	Europe, Asia, Western North America



FIG. 142.—*Cimicifuga racemosa*—Plant and rhizome. Note the pinnately decomposed leaf and the wand-like racemes which bear white flowers. (Sayre.)

Official drug	Part used	Botanical name	Habitat
Staphisagria	Seed	Delphinium Staphisagria	South Europe, Asia Minor
Cimicifuga	Rhizome and root	Cimicifuga racemosa	North America, Europe, Asia
Pulsatilla N.F.	Entire herb	{ Anemone Pulsatilla Anemone Ludoviciana Anemone pratensis }	{ Europe
Coptis N.F.	Entire herb	Coptis trifolia	United States and Canada
Adonis N.F.	Entire herb	Adonis vernalis	Europe
Delphinium N.F.	Seeds	{ Delphinium Consolida Delphinium Ajacis }	{ Europe
<b>Unofficial</b>			
Aconiti Folia	Leaves and flower tops	Aconitum Napellus	Europe, Asia, western North America
Helleborus	Rhizome and roots	Helleborus niger	Alps

*Berberidaceæ* or *Barberry Family*.—Herbs and woody plants with watery juices and alternate, or radical, simple or compound leaves often bearing spines or barbs, which give them a barbed appearance. Fruit a berry or capsule.

Official drug	Part used	Botanical name	Habitat
Berberis N.F.	Rhizome and roots	Berberis species of the Sect. Odostemon	Western North America
Podophyllum	Rhizome and roots	Podophyllum peltatum	Eastern North America
Caulophyllum N.F.	Rhizome and roots	Caulophyllum thalictroides	Eastern United States

*Menispermaceæ*, or *Moonseed Family*.—Choripetalous woody, climbing, tropical plants with alternate, exstipulate, simple often peltate leaves. Flowers green to white. Fruit a one-seeded succulent drupe. Seeds albuminous. They usually contain tonic, narcotic or poisonous bitter principles.



FIG. 143.—*Podophyllum peltatum*. Entire plant, above ground portion, and fruit. Note the flowering stems bearing in each instance two one-sided leaves and a nodding flower from the fork. This plant also sends up from its rhizome flowerless stems each of which terminates in a 7-9 lobed peltate leaf.

Official drug	Part used	Botanical name	Habitat
Calumba	Root	<i>Jateorhiza palmata</i>	East Africa
Pareira N.F.	Root	<i>Chondodendron tomentosum</i>	Peru and Brazil
Cocculus N.F.	Fruit	<i>Anamirta cocculus</i>	Asia
<b>Unofficial</b>			
Menispermum	Rhizome and roots	<i>Menispermum canadense</i>	United States and Canada



*Myristicaceæ* or *Nutmeg Family*.—An order of apetalous trees comprising the single genus *Myristica*, of about 80 species.

*Myristica*.—A large tropical genus of fragrant, apetalous trees—the nutmegs—coextensive with the nutmeg family, having alternate,

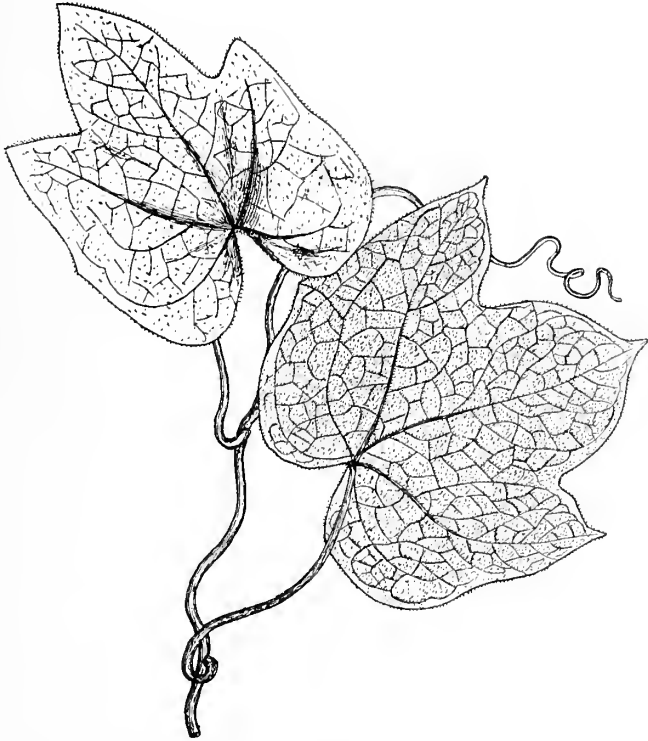


FIG. 144.—*Jateorhiza palmata*—Portion of vine. Note tendril for winding about a support as this plant climbs. (Sayre.)

entire, often punctate leaves, small diœcious regular flowers, and a succulent, two-valved, one-celled fruit with a solitary seed, usually covered by a fleshy arillus.

*M. fragrans*, a handsome tree, 20 to 30 feet high, of the Malay archipelago, supplies the nutmegs and mace of commerce.

Official drug	Part used	Botanical name	Habitat
Myristica	Kernel of seed	<i>Myristica fragrans</i>	Molluca Islands
Oleum Myristicæ	Volatile oil	<i>Myristica fragrans</i>	
Macis N.F.	Arillode	<i>Myristica fragrans</i>	



FIG. 145.—*Myristica fragrans*—Branch and fruit. (Sayre.)

*Lauracæ* or *Spicebush Family*.—Shrubs or trees of sub-tropical or tropical, rarely of temperate regions. Bark, wood and leaves rich in spicy aromatic hydrocarbon oils. Leaves alternate, simple, entire, often leathery shining. Inflorescences usually cymose clus-

ters. Flowers small, green, yellow or rarely whitish, hermaphrodite or more or less diœcious, regular calyx alone present as a floral whorl, of three to six small sepals. Stamens four to twelve in several rows of three to four each; anthers opening by recurved valves (valvular



FIG. 146.—*Cinnamomum zeylanicum*—Branch. (Sayre.)

dehiscence). Pistil monocarpellary, ovary superior one-celled with solitary pendulous ovule, style simple with usually rounded stigma. Fruit a succulent berry (Spicebush and “*Bacca laurea*”) or a succulent drupe (*Sassafras*).

Official drug	Part used	Botanical name	Habitat
Camphora	Ketone	Cinnamomum Camphora	Eastern Asia
Sassafras	Bark of root	Sassafras variifolium	North America
Sassafras Medulla N.F.	Pith	Sassafras variifolium	North America
Cinnamomum Zeylanicum	Bark	Cinnamomum Zeylanicum	Ceylon
Cinnamomum Saigonicum	Bark	Undetermined species of cinnamon	China
Oleum Cinnamomi	Volatile oil	Cinnamomum cassia	China
<b>Unofficial</b>			
Coto	Bark	Sp. undetermined	Bolivia
Laurus	Leaves	Laurus nobilis	Europe North America
Fagot cassia	Bark	Cinnamomum Burmanii	Asia
Clove Bark	Bark	Dicypellium caryophyllatum	Brazil
Cassia Buds	Immature fruit	Cinnamomum Loureirii	China

**XII. Order Rhœadales (Papaverales).**—*Papaveraceæ* or *Poppy Family*.—Herbs or low shrubs. Root only, in some cases root and stem, and in still others the entire plant, traversed by anastomosing latex tubes that contain a milky juice varying from white (*Papaver*) or pale-yellow (*Chelidonium*) to red (*Bloodroot*). Latex tubes wholly confined to cortex or phloem but occasionally sending branches into the medullary rays, rarely into the pith of the plant. Leaves alternate varying from simple (*Platystemon*) to pinnatifid, pinnatifid or even pinnately compound. Inflorescence varying from a loose raceme or panicle of cymes to a raceme of cymes or condensing until, as in *Papaver*, only one large terminal flower is left. Flowers regular, tetramerous or dimerous. Sepals typically two more rarely three. Petals typically four, more rarely six. Stamens indefinite in most forms, hypogynous except in California Poppy (*Eschscholtzia*) where hypogyny is modified into perigyny. Pistil of sixteen to four, rarely two carpels generally fused together. Placenta parietal. Ovules

numerous, anatropous. Fruit a capsule except in *Platystemon* which has follicles. Seeds richly albuminous.



FIG. 147.—*Papaver Somniferum*—Flowering branch and fruit. (Sayre.)

Official drug	Part used	Botanical name	Habitat
Opium	Air-dried milky exudate	<i>Papaver somniferum</i> and its <i>var. album</i>	Eastern Mediterranean countries
Sanguinaria	Rhizome and roots	<i>Sanguinaria canadensis</i>	
Unofficial Chelidonium	Entire flowering plant	<i>Chelidonium majus</i>	United States and Canada
Maw seed	Seeds	<i>Papaver somniferum album</i>	<i>vide supra</i>

*Fumariaceæ* or *Fumitory Family*.—Delicate herbs rarely shrubs containing milky watery to watery latex. Leaves more or less compound. Inflorescence a raceme or spike. Flowers irregular, zygomorphic, one or both of the petals of which having a spur. Fruit a one-chambered capsule. Seeds albuminous. Idioblasts common.

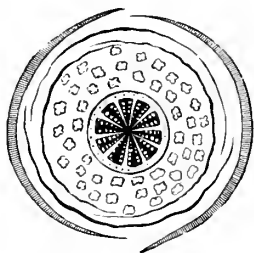


FIG. 148.—Transverse section of flower of Poppy. (Sayre.)



FIG. 149.—Gynecium of Poppy, with one stamen remaining. (Sayre.)

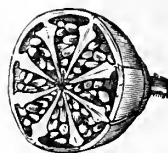


FIG. 150.—Transverse section of ovary of Poppy. (Sayre.)

Official drug	Part used	Botanical name	Habitat
Corydalis N.F.	Tubers of <i>Dicentra</i> ( <i>Bicuculla</i> )		United States and Canada
	canadensis		
	Bulbs of <i>Dicentra</i> <i>Cucullaria</i>		

*Cruciferae* or *Mustard Family*.—Herbs, rarely shrubs, mostly of temperate regions. Stem and branches upright or diffuse spreading (*Arabis*). Leaves alternate, simple rarely compound, exstipulate, entire or toothed, often more or less hairy. Inflorescence at first a corymb or shortened raceme, later elongating into a loose raceme. Bracts at base rarely reduced, usually absent. Flowers regular—rarely irregular (*Candytuft*)—tetramerous. Sepals four, green, equal or two laterals, at times pouched as nectar receptacles. Petals four, yellow to white or to pink or purple, cruciform, often divisible into claw and blade. Stamens six to four long anteroposterior, two short lateral and often with nectar knobs or discs, hence termed tetradynamous, insertion hypogynous. Pistil syncarpous bicarpellate, superior, carpels lateral. Ovary one-celled but falsely two-celled by a placental replum, style simple, stigma rounded or bifid or bilobed. Ovules several, rarely few, attached to marginal

placenta. Fruit a capsule—rarely indehiscent—bursting lengthwise by two valves. Seeds exalbuminous.

Official drug	Part used	Botanical name	Habitat
Sinapis Alba	Seed	Sinapis alba	Europe and Asia
Sinapis Nigra	Seed	Brassica nigra	Europe and Asia
<b>Unofficial drug</b>			
Semen Rapæ	Seed	Brassica napus	Europe and Asia



FIG. 151.—*Brassica nigra*—Branch. (Sayre.)

**XIII. Order Sarraceniales.**—*Droseraceæ* or *Sundew Family*.—Herbs (*Drosera*, *Dionaea*, etc.) rarely shrubs (*Roridula* of South Africa) growing in bogs or swamps or purely aquatic in habit (*Aldrovanda*). Leaves, either rosettes or more or less scattered in alternate fashion over stem, usually glandular-hairy or sensitive-hairy and insectivorous. Inflorescence a loose raceme or cymose

umbel. Flowers regular, pentamerous; sepals five, aposepalous green; petals apopetalous, varying from white to whitish-pink, pink scarlet, purple to bluish-purple; stamens varying from fifteen to five, hypogymous; pistil syncarpous of five to three, rarely fewer carpels. Fruit a capsule. Seeds albuminous.



FIG. 152.—*Drosera rotundifolia*. Production of a young plant from the leaf of an older plant. (Gager.)

Official drug	Part used	Botanical origin	Habitat
Drosera N.F.	Entire plant	{ <i>Drosera rotundifolia</i> <i>Drosera intermedia</i> <i>Drosera longifolia</i>	Eastern and Western Hemispheres

XIV. Order Rosales.—*Saxifragaceæ* or *Saxifrage Family*.—Herbs (*Saxifraga*, *Mitella*, etc.) or shrubs (*Hydrangea*, *Ribes*, *Philadelphus*, etc.), rich in tannin content, with opposite or alternate leaves usually devoid of stipules. Both stamens and petals are generally inserted on the calyx. Fruit a follicle, capsule, or berry. Seeds with copious albumen.



Official drug	Part used	Botanical name	Habitat
Hydrangea N.F.	Rhizome and roots	Hydrangea arborescens	United States

*Hamamelidaceæ* or *Witchhazel Family*.—Shrubs or small or large trees. Leaves, simple, alternate and pinnately veined; stipules deciduous to caducous, paired and slightly fused at the bases of



FIG. 153.—*Liquidambar orientalis*—Branch. (Sayre.)

petioles. Flowers frequently yellow to yellowish-white, in axillary clusters or heads or spikes, hermaphrodite or monœcious; sepals and petals five to four rarely indefinite, superior (petals absent in *Fothergilla*); stamens twice as many as the petals but the outer row alone fertile, the inner row being more or less barren and scale-like;

gynœcium of two carpels united below. Fruit a two-beaked, two-celled woody capsule dehiscing at the summit, with a bony seed in each cell, or several, only one or two of them ripening.

Official drug	Part used	Botanical name	Habitat
Styrax	Balsam from wood and inner bark	Liquidambar orientalis	The Levant
Hamamelidis Folia N.F.	Leaves	Hamamelis virginiana	United States and Canada

*Rosaceæ or Rose Family.*—Herbs, shrubs, or trees mostly of temperate regions. Stem and branches upright or creeping (Strawberry, Cinquefoil), herbaceous to woody. Leaves alternate, stipulate (stipules green persistent to scaly deciduous), compound condensing to "simple." Flowers regular, pentamerous; sepals and petals five—rarely four—inferior to ovary becoming by stages superior to it. Sepals green—at times with epicalyx (Strawberry, Cinquefoil, etc.), persistent round fruit. Petals usually yellow to white or to pink, crimson, rarely purple, rosaceous, deciduous. Stamens indefinite, perigynous (Strawberry, etc.), to semi-epigynous (Rose, Peach, etc.), and epigynous (Apple, Pear). Pistil apocarpous with many (Strawberry, Rose) carpels or fewer to five (Apple), or two to one (Plum, Cherry), becoming falsely fused by union with up-growing receptacle (Hawthorn, Apple). Fruit a collection of achenes on dry (Cinquefoil) or succulent receptacle (Strawberry), or dry follicles (Bridal Wreath), or drupels (Blackberry), or a drupe (Peach, Plum, Cherry), or a pome (Apple, Pear). Seeds exalbuminous, embryo filling seed cavity.

Official drug	Part used	Botanical name	Habitat
Amygdala Dulcis	Seed	Prunus amygdalus variety dulcis	Asia
Prunus Virginiana	Bark	Prunus serotina	United States and Canada
Rubus N.F.	Bark of rhizome	Rubus villosus, R. cuneifolius, and R. nigrobaccus	United States
Quillaja N.F.	Bark	Quillaja Saponaria	Chile and Peru
Brayera N.F.	Panicles of pistillate flowers	Hagenia abyssinica	Abyssinia

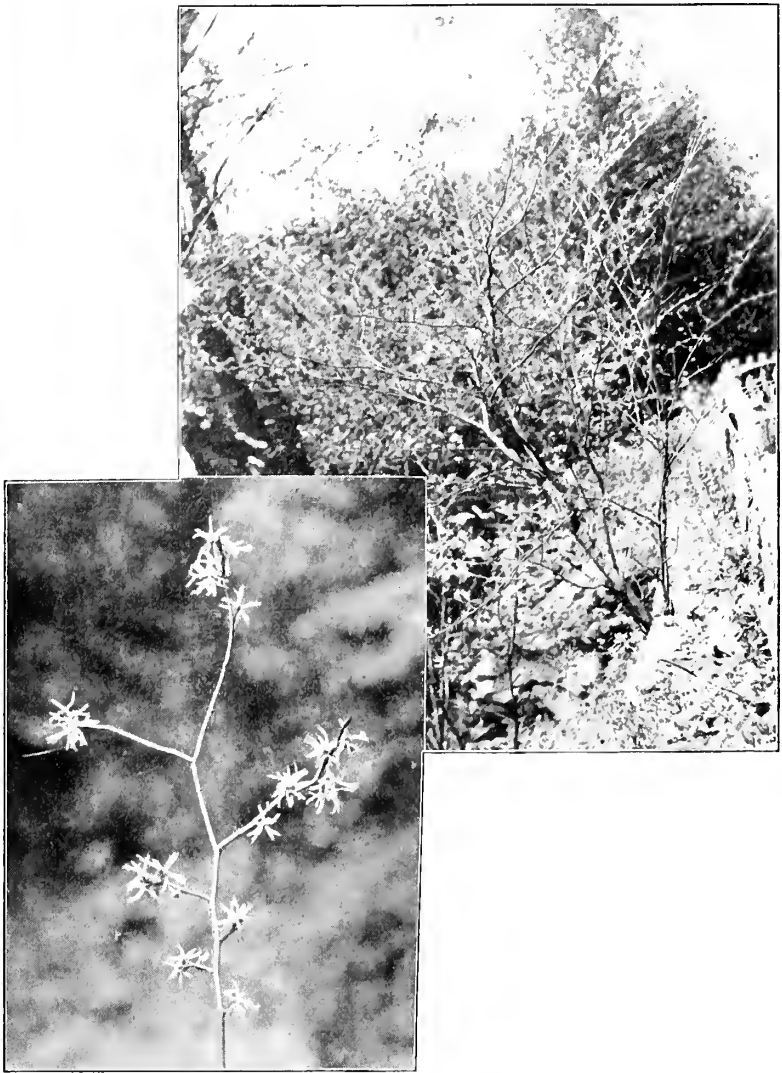


FIG. 154.—*Hamamelis virginiana*. Upper figure shows this shrub as it appears in autumn after the leaves have fallen. Note that the plant is in blossom. Lower figure shows a flowering branch from the same plant. The bright yellow flowers occur in axillary clusters appearing at the same time as the ripening of fruits from blossoms of the previous year.

Official drug	Part used	Botanical name	Habitat
Rosa Gallica	Petals	Rosa gallica	Southern Europe
Rubi Fructus N.F.	Fresh fruit	Rubus nigrobaccus and Rubus villosus	United States
Succus Pomorum N.F.	Juice of Fruit	Pyrus Malus (cultiv. var's.)	Cultivated
Rubi Idæi Fructus N.F.	Juice of Fruit	Rubus Idæus and Rubus strigosus	Europe and Asia
Prunum N.F.	Fruit	Prunus domestica	Southern Europe



FIG. 155.—*Quillaja saponaria*—Branch. (Sayre.)

Unofficial drug	Part used	Botanical name	Habitat
Amygdala Amara	Seed	<i>Prunus amygdalus</i> var. <i>amara</i> .	Asia Minor, Persia, Syria
Cydonium	Seed	<i>Cydonia vulgaris</i>	Cultivated widely
Rosa Centifolia	Petals	<i>Rosa centifolia</i>	Western Asia
Rosa Canina	Spurious Fruit	<i>Rosa canina</i>	Europe
Tormentilla	Rhizome	<i>Potentilla</i> <i>silvestris</i>	Europe and Asia



FIG. 156.—*Prunus domestica*—Fruiting branch and flowering branch. (Sayre.)

*Leguminosæ* or *Pea Family (Fabaceæ)*.—Herbs, shrubs or trees of all regions, with tuberclcd roots. Stem usually erect, rarely creeping (*Trifolium repens*). Leaves alternate, compound—rarely simple—stipulate, sometimes tendriform or reduced to phylloid petioles (*Acacia* sp.). Inflorescence a raceme, at times, condensed almost to a head or capitulum (Sp. of clover, *Mimosa*, etc.). Flowers pentamerous (rarely four), regular (*Mimosæ*), to irregular (*Cæsalpineæ*, *Papilionaceæ*). Sepals five united, green; petals five

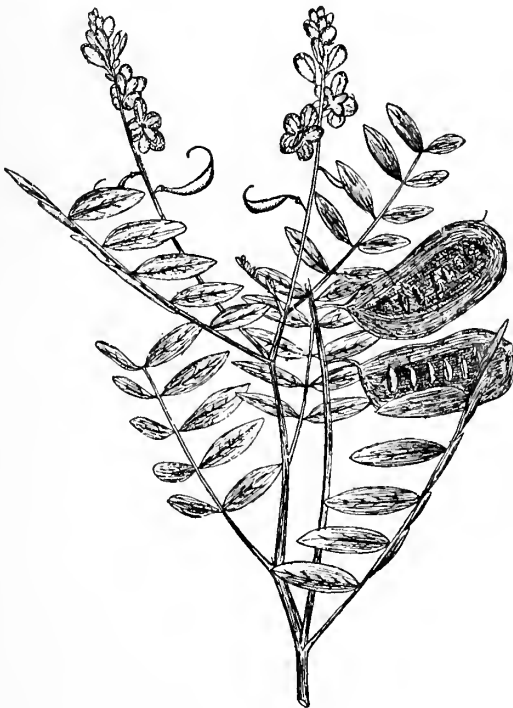
(rarely four) variously related, in Papilionaceæ one superior, external, posterior—standard or vexillum, two lateral form wings or alæ, two inferior internal and anterior slightly adherent form Keel.



FIG. 157.—*Glycyrrhiza glabra*—Branch. (Sayre.)

Stamens ten to four, free or in Papilionaceæ united by filaments into a monadelphous (ten) or a diadelphous (nine to one) tube, inserted perigynously. Pistil monocarpellary, ovary with sutural placentation, style simple. Seeds exalbuminous.

Official drug	Part used	Botanical name	Habitat
Acacia	Gummy exudation	Acacia Senegal and other African species	Africa
Tragacantha	Gummy exudation	Astragalus gum- mifer and other Asiatic species	Asia
Balsamum Peruvianum	Balsam	Toluifera Pereiræ	Central America
Balsamum Tolutanum	Balsam	Toluifera Balsamum	Columbia
Hæmatoxylon N.F.	Heartwood	Hæmatoxylon campechianum	Central America
Santalum Rubrum	Heartwood	Pterocarpus santalinus	Indo China



[ FIG. 158.—*Cassia acutifolia*—Branch showing flower and fruit. (Sayre.)

Official drug	Part used	Botanical name	Habitat
Glycyrrhiza	Rhizome and roots	Glycyrrhiza glabra	Spain and France
		Glycyrrhiza glandulifera	Southwestern Asia, Russia
Senna	Leaflets	Cassia acutifolia	Egypt
Cassia Fistula N.F.	Fruit	Cassia angustifolia	Arabia and India
		Cathartocarpus fistula	India
Tamarindus N.F.	Pulp of fruit	Tamarindus indica	Tropical Africa
Copaiba	Oleoresin	Copaiba species	South America
Chrysarobinum	Neutral principle	Vouacapoua Araroba	Brazil
Physostigma	Seed	Physostigma venenosum	Africa
Kino	Inspissated juice	Pterocarpus Marsupium	India and Ceylon
Scoparius N.F.	Tops	Cytisus scoparius	Europe
Trifolium N.F.	Inflorescence	Trifolium pratense	United States
Galega N.F.	Flowering tops	Galega officinalis	Southern Europe
Baptisia N.F.	Roots	Baptisia tinctoria	Eastern United States and Canada
Krameria N.F.	Root	Krameria triandra	Peru and Bolivia
		Krameria Ixina	United States of Colombia, Brazil
		Krameria argentea	Brazil
<b>Unofficial</b>			
Fœnum græcum	Seed	Trigonella Fœnum-græcum	Mediterranean region
Piscidia	Bark	Piscidia Erythrina	West Indies
Indigo	Coloring matter	Indigofera tinctoria	India
Melilotus	Leaves and flowering tops	Melilotus officinalis	Europe
Soy Bean	Seeds	Glycine hispida	United States and Europe
Abrus	Seeds	Abrus precatorious	Tropics and sub-tropics
Catechu	Extract	Acacia Catechu	India
Mucuna	Hairs from fruits	Mucuna pruriens	East and West Indies

**XV. Order Geraniales (Gruinales).—Geraniaceæ or Geranium Family.**—Herbaceous, rarely semi-succulent sub-shrubby plants. Stems cylindrical, often hairy or glandular hairy. Leaves alternate



to opposite, stipulate; venation from pinnate to palmate, so leaf shape from ovate to pinnatifid to pinnatipartite to sub-palmatifid to palmatifartite to compound palmate. Inflorescence either a dichsial or scorpid cyme. Flowers regular pentamerous (*Geranium*)



FIG. 159.—*Physostigma venenosum*—Portion of plant and fruit. (Sayre.)

to irregular pentamerous (*Pelargonium*); sepals five, aposepalous; petals five, apopetalous, varying in color from greenish-white or pink-red to scarlet, scarlet-crimson to crimson-purple; stamens with anthers ten or five, hypogynous or inserted into slightly developed hypogynous disc; pistil pentacarpellary, ovary five-celled with two, rarely one ovule in each cell, styles elongate, fused round a stylar

column of receptacle then continued as a stylar tip which splits into five stigmatic surfaces. Fruit a regma rarely a simple capsule. Regma splits into five recurved carpels, each then dehiscent to set free two or one seeds. Seeds exalbuminous.

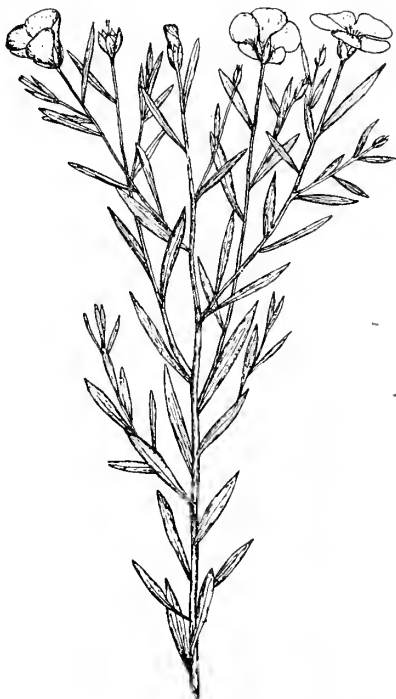


FIG. 160.—*Linum usitatissimum*. (Sayre.)

Official drug	Part used	Botanical name	Habitat
Geranium N. F.	Rhizome	<i>Geranium maculatum</i>	North America
Unofficial			
Oil of Rose } Geranium }	Volatile oil	<div style="display: flex; align-items: center;"> <div style="font-size: 2em; margin-right: 5px;">{</div> <div style="margin-right: 5px;">Pelargonium</div> <div style="margin-right: 5px;">odoratissimum</div> <div style="margin-right: 5px;">Pelargonium Radula</div> <div style="margin-right: 5px;">Pelargonium</div> <div style="margin-right: 5px;">capitatum</div> <div style="font-size: 2em; margin-left: 5px;">}</div> </div>	Mediterranean regions

*Linaceæ* or *Flax Family*.—Herbs with slender stems and alternate, simple, narrow leaves. Inflorescence cymose with regular

pentamerous flowers; pistil five-carpelled with a five-celled ovary containing two ovules in each cavity and having a single style with knob-like stigma. While the flower is still in bud condition or soon after, there commences an ingrowth of the mid-rib of each carpel which proceeds until when plant is in fruit there are formed 10 cavities each enclosing a seed. Seeds, anatropous, mucilaginous, flattened, containing a large embryo and slight albumen.

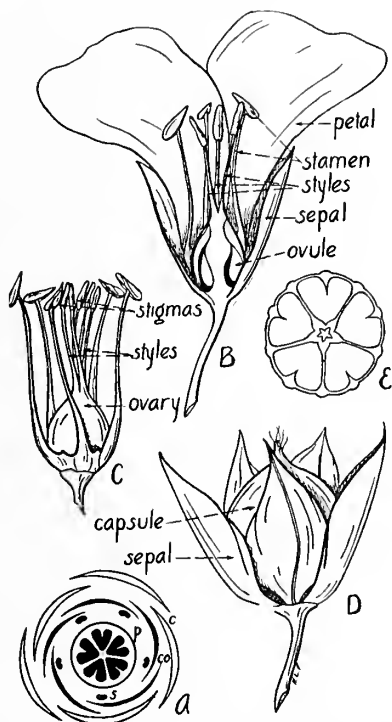


FIG. 161.—Flax. A, floral diagram—*c*, calyx; *co*, corolla; *s*, stamens; *p*, pistil. B, median lengthwise section of flower. C, calyx and corolla removed. D, fruit, external view. E, cross-section of fruit. (Robbins.)

Official drug	Part used	Botanical name	Habitat
Linum	Seeds	<i>Linum usitatissimum</i>	Temperate regions
Oleum Lini	Fixed oil	<i>Linum usitatissimum</i>	

*Erythroxylaceæ* or *Coca* Family.—Shrubs (*Erythroxylon*) or trees with alternate, simple, entire, glabrous and pinnately veined leaves. Flowers regular, hermaphroditic, each with five sepals, five hypogynous petals, ten stamens and a two- to three-celled ovary subtending three styles each with a capitate stigma. Fruit an ovoid, angular, one-celled drupe containing a single seed.

Official drug	Part used	Botanical origin	Habitat
Cocaina	Alkaloid	<i>Erythroxylon</i> Coca and its varieties	Peru and Bolivia
<b>Unofficial</b>			
Coca	Leaves	<i>Erythroxylon</i> Coca and its varieties	Peru and Bolivia



FIG. 162.—*Guaiacum sanctum*—Flowering branch. (Sayre.)

*Zygophyllaceæ* or *Caltrop Family*.—Herbs, shrubs or trees (*Guaiacum*) having jointed, often divaricate branches. Leaves usually opposite, stipulate and compound. Flowers regular or irregular, pentamerous, white, yellow, red or blue (*G. officinale*). Fruit a capsule.

Official drug	Part used	Botanical origin	Habitat
Guaiacum	Resin of wood	{ <i>Guaiacum officinale</i> <i>Guaiacum sanctum</i>	{ Tropical and sub-tropical America
Guaiaci Lignum N. F.	Heartwood	<i>G. officinale</i> and <i>G. sanctum</i>	Tropical and sub-tropical America



FIG. 163.—*Citrus Aurantium*—Branch. (Sayre.)

*Rutaceæ* or *Rue Family*.—Herbs (*Ruta*, *Diosma*, *Barosma*) or shrubs (*Xanthoxylum*) or trees (*Citrus*). Stems upright, often wiry xerophytic, in sub-family *Ruteæ*, elongated and spiny in sub-family

*Zanthoxyleæ*, woody and green in sub-family—*Aurantieæ*. Leaves alternate or opposite, simple (*Ruta*), rarely whorled (*Pilocarpus*) or



FIG. 164.—*Barosma betulina*—  
Branch and flower. (Sayre.)

pinnatifid, as in *Ruta graveolens*, or pinnate, as lower parts of *Ruta graveolens*, becoming reduced pinnate in *Citrus Aurantium*. Leaves exstipulate or with spiny stipules (*Xanthoxylum*). Stems and leaves abound in more or less sunken glands. Flowers pentamerous, varying in color from yellow in *Ruta* to white in *Citrus* to pink (*Barosma betulina*) or pink crimson as in some *Barosma* and *Diosma* species, rarely to pinkish-purple (*Pilocarpus*); sepals five, aposepalous becoming in *Citrus* more or less synsepalous; petals five, apopetalous becoming more or less synpetalous and tubular (*Correa grandiflora*); stamens five, simple or with expanded bases, lobed, or lobes developed as staminal stipules and more or less split (*Citrus*); pistil of ten, five, three or two carpels, ovary as many-celled. Fruit a capsule (*Dittany, Xanthoxylum*), berry (*Citrus*)

or rarely a samara (*Ptelea*). Seeds albuminous or exalbuminous. Many of the plants contain volatile oils in their secretory cavities.

Official drug	Part used	Botanical origin	Habitat							
Aurantii Dulcis Cortex	Outer rind of ripe fruit	<i>Citrus Aurantium sinensis</i>	Sub-tropics							
Aurantii Amari Cortex	Rind of fruit	<i>Citrus Aurantium amara</i>	Northern India							
Limonis Cortex	Outer rind of ripe fruit	<i>Citrus medica</i> Limonum	Northern India							
Pilocarpus	Leaflets	<table border="0"> <tr> <td>{</td> <td><i>Pilocarpus Jaborandi</i></td> <td rowspan="3">}</td> <td rowspan="3">Brazil</td> </tr> <tr> <td></td> <td><i>Pilocarpus</i></td> </tr> <tr> <td></td> <td><i>microphyllus</i></td> </tr> </table>	{	<i>Pilocarpus Jaborandi</i>	}	Brazil		<i>Pilocarpus</i>		<i>microphyllus</i>
{	<i>Pilocarpus Jaborandi</i>	}	Brazil							
	<i>Pilocarpus</i>									
	<i>microphyllus</i>									

Official drug	Part used	Botanical origin	Habitat
Buchu	Leaves	Barosma betulina and B. serratifolia	Cape Colony
Xanthoxylum	Bark	{ Xanthoxylum americanum Xanthoxylum Clava-Herculis	Northern United States Southern United States
Oleum Bergamottæ N.F.	Volatile oil	Citrus Aurantium Bergamia	France, Italy
Oleum Aurantii Florum N.F.	Volatile oil	Citrus Aurantium amara	Northern India
Succus Citri N.F.	Juice	Citrus medica acida	Asia
Xanthoxyli Fructus N.F. }	Capsules	{ Xanthoxylum americanum Xanthoxylum Clava-Herculis	Northern United States Southern United States
<b>Unofficial</b>			
Ruta	Leaves	Ruta graveolens	Southern Europe
Ptelea	Bark of root	Ptelea trifoliata	North America
Belæ Fructus	Unripe fruit	Ægle Marmelos	Malabar, Coromandel

*Simarubaceæ* or *Ailanthus* Family.—A family of chiefly tropical shrubs or trees containing bitter principles. The leaves are alternate and pinnate. The flowers are diœcious or polygamous and arranged in axillary panicles (*Picrasma excelsa*) or racemes (*Quassia amara*). The plants are distinguished from those of the *Rutaceæ* by the absence of secretory cavities.

Official drug	Part used	Botanical origin	Habitat
Quassia	Wood	{ Picrasma excelsa Quassia amara	West Indies Surinam
<b>Unofficial</b>			
Simaruba	Bark of root	{ Simaruba officinalis Simaruba amara	South America Central America, Bahamas and Florida

*Burseraceæ* or *Myrrh* Family.—Shrubs and trees of tropical climes having secretion reservoirs in their bark. Leaves alternate and compound. Flowers small, regular and hermaphrodite arranged in racemes or panicles. Fruit a drupe.

Official drug	Part used	Botanical origin	Habitat
Myrrha	Gum resin	Commiphora species	East Africa and Arabia
Unofficial Olibanum	Gum resin	Boswellia carterii	East Africa and Arabia



FIG. 165.—*Pterasma excelsa*—Branch. (Sayre.)

*Meliaceæ* or *Mahogany Family*.—Tropical trees or shrubs with wood often hard, colored and odoriferous. Leaves alternate, ex-



stipulate, pinnately compound, rarely simple and entire. Inflorescence a terminal or axillary raceme. Flowers hermaphrodite or rarely polygamo-dioecious, regular; sepals five to four, small; petals usually five to four, hypogynous; stamens generally ten to eight, rarely

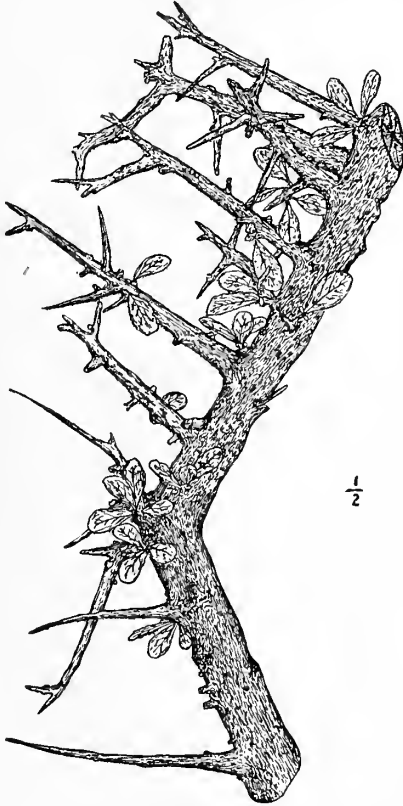


FIG. 166.—*Commiphora myrrha*—Branch. (Sayre.)

five, very rarely twenty to sixteen, inserted outside the base of the hypogynous disc; filaments united into a tube; carpels usually five to three; style simple; ovary free, usually five- to three-celled. Fruit a drupe (*Melia*), berry (*Vavaea*), or capsule (*Cedrella*). Seeds exalbuminous or with fleshy albumen.

Official drug  
Cocillana N.F.

Part used  
Bark

Botanical origin  
Guarea Rusbyi

Habitat  
Bolivia

*Polygalaceæ* or *Milkwort Family*.—Herbs or shrubs with upright, herbaceous to woody stems often branching profusely, the branches occasionally becoming geotropic or subterranean and bearing



FIG. 167.—*Polygala senega*—Plant and rhizome. (Sayre.)

cleistogamous flowers. Leaves simple, often lanceolate or linear, exstipulate, alternate. Inflorescence a raceme, spike (*Polygala Senega*) or head (*P. lutea*). Flowers irregular, hermaphroditic

with commonly eight stamens. Fruit a two-celled capsule (*P. Senega*), rarely a drupe or samara. Pollen grains barrel-shaped.

Official drug	Part used	Botanical origin	Habitat
Senega	Root	Polygala Senega	United States and Canada

*Euphorbiaceæ* or *Spurge Family*.—Often herbaceous, more rarely shrubby, rather seldom arborescent plants. Stem, leaves and other parts in several genera traversed by latex canals that are either ramifying cells (*Euphorbias*) or laticiferous vessels (*Manihot*, *Hevea*, etc.) or rows of laticiferous sacs (*Micrandra*) and contain a white latex with acid often poisonous contents or alkaloid or hydrocarbon, at times, rubber contents. Leaves alternate, exstipulate to stipulate, simple to pinnate or palmate. Inflorescence cymose. Flowers usually as in *Ricinus*, etc., pentamerous, dichinous; sepals five, green, aposepalous, becoming rudimentary or absent in *Anthostema* and *Euphorbia*. Petals none or five more or less petaloid; stamens numerous to ten to five or one (*Euphorbia*); pistil in pistillate flowers rarely of twenty to ten apocarpous or loosely syncarpous carpels (Sandbox tree), commonly of three syncarpous carpels with distinct radiate styles; ovary as many-celled as carpels with two to one ovules in each cell. Fruit a tricoccoid regma or capsule, rarely winged, indehiscent, nut-like. Seeds with oily endosperm. Flowers at times surrounded and subtended by more or less petaloid and expanded bracts and bracteoles.

Official name	Part used	Botanical origin	Habitat
Euphorbia	Herb	Euphorbia pilulifera	Tropics and subtropics
Pilulifera N.F.			
Stillingia	Root	Stillingia sylvatica	Southern United States
Oleum Ricini	Volatile oil	Ricinus communis	Asia and Africa
Oleum Tiglij	Volatile oil	Croton tiglium	Asia
Cascarilla N.F.	Bark	Croton Eluteria	West Indies
<b>Unofficial</b>			
Tapioca	Starch	Manihot utilissima	South America
Kamala	Hairs of capsule	Mallotus philippinensis	Asia
Elastica	Prepared latex	Hevea braziliensis and other species	Brazil

**XVI. Order Sapindales.**—*Anacardiaceæ* or *Sumac Family*.—Shrubs or trees producing in stems and leaves secretion contents that are either acrid watery or acrid opalescent or white viscid, viscid acrid and poisonous. Leaves alternate, rarely opposite, simple (*Rhus Cotinus*), three-foliolate (*Rhus toxicodendron*) or pinnate (*Rhus glabra*, *R. venenata*, etc.). Inflorescence frequently terminal and composed of racemes or cymes, often reduced to a simple raceme. Flowers small, clustered, green, greenish-white to greenish-yellow; sepals five, rarely six or four green, small; petals five smaller than sepals; stamens equal in number to the petals and alternate, rarely fewer, sometimes double in number, rarely indefinite, inserted hypogynously or upon an enlarged disc that surrounds or swells up between stamens and pistil; pistil monocarpellary more rarely bicarpellary, very rarely as in *Spondiææ* of ten to five carpels, ovary one-celled with single ovule. Fruit a drupe. Seeds exalbuminous with large embryo filling seed cavity.

Official drug	Part used	Botanical origin	Habitat
Rhus Glabra N.F.	Ripe fruits	Rhus glabra	Canada and United States
Mastiche N.F.	Concrete resin- ous exudate	Pistacia Lentiscus	Grecian Archipelago
<b>Unofficial</b>			
Chinese Galls	Excrescences	Rhus semialata	China
Japanese Galls	Excrescences	Rhus japonica	Japan
Rhus Typhina	Ripe fruits	Rhus typhina	United States
Acajou Gum	Gum	Anacardium occidentale	West Indies
Pistachio	Seeds	Pistacia vera	Western Asia
Anacardium	Fruit	Anacardium occidentale	West Indies
Rhus Toxicodendron	Fresh leaflets	Rhus toxicodendron	United States

*Celastraceæ* or *Staff Tree Family*.—Shrubs (*Euonymus*), or shrubby climbers (*Celastrus*). Leaves alternate, rarely opposite, simple, entire or toothed. Inflorescence of axillary cymes or terminal racemes. Flowers perfect (*Euonymus*, *Pachistima*) or polygamo-dioecious (*Celastrus*) greenish (*Celastrus*), greenish or yellowish-white (*Euonymus Europæus*), greenish-purple (*Euonymus americanus*) to dark-purple

(*Euonymus atropurpureus*); calyx four to five-lobed; corolla of four to five petals; stamens four to five, perigynous, inserted on a disc, which fills the base of the calyx and sometimes covers the ovary; ovary three- to five-celled. Fruit a two- to five-celled capsule.



FIG. 168.—*Euonymus atropurpureus*. Flowering branch to left; fruiting branch to right.

Seeds albuminous with fleshy succulent reddish aril (*Euonymus*, *Celastrus*) or white membranous aril (*Pachistima*).

Official drug	Part used	Botanical origin	Habitat
Euonymus N.F.	Bark of root	<i>Euonymus</i> <i>atropurpureus</i>	United States

*Sapindaceæ* or *Soapwort Family*.—Trees, shrubs, undershrubs or rarely herbs of tropical climes containing the glucoside saponin. Stem erect or climbing (*Paullinia*) often provided with tendrils. Leaves commonly alternate and compound. Flowers in racemes

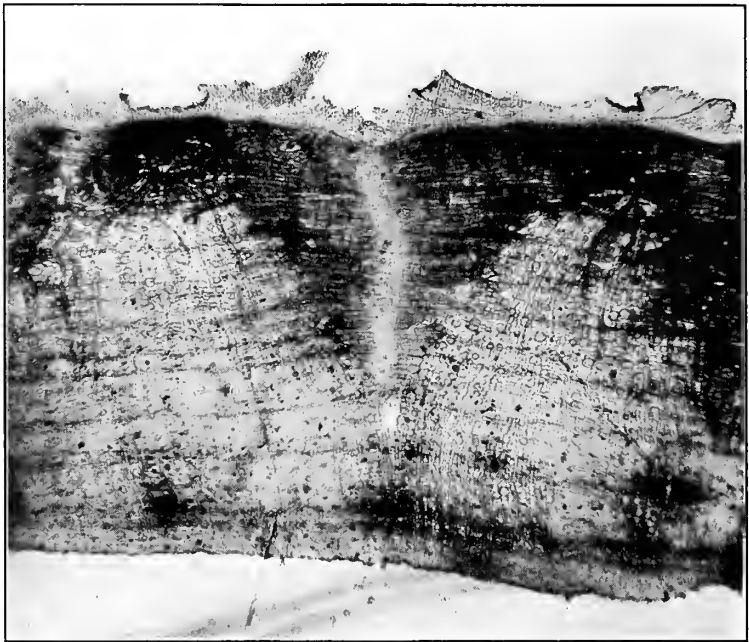


FIG. 169.—Cross section through root-bark of *Euonymus atropurpureus*. Note the two broad dome-shaped phloem patches, one on either side of a wedge-shaped primary medullary ray.

or panicles (*Paullinia*), perfect or polygamo-dioecious, yellowish in *Paullinia Cupana*. Fruit a capsule (*P. Cupana*), samara, drupe or berry. Seeds exalbuminous.

Official drug	Part used	Botanical origin	Habitat
Guarana	Dried Paste, chiefly of crushed seeds	<i>Paullinia Cupana</i>	Brazil

*Aceraceæ* or *Maple Family*.—Chiefly trees, occasionally shrubs, of temperate regions with watery sap. Leaves opposite, simple and palmately lobed, cleft (*Acer*) or pinnate (*Negundo*). Inflorescence a raceme condensing in some species to a capitulum of cymes. Flowers small, regular, polygamous or diœcious; sepals five to four green; petals none or five, variously colored; stamens usually eight, hypogynous or perigynous; nectar disc around stamens or between them and pistil; pistil bicarpellary with two-celled ovary. Fruit a samara. Seeds green exalbuminous with coiled or folded embryo and long thin cotyledons.

Unofficial drug	Part used	Botanical origin	Habitat
Acer Spicatum	Bark	Acer spicatum	United States

**XVII. Order Rhamnales.**—*Rhamnaceæ* or *Buckthorn Family*.—Shrubs or low trees usually of branching or spreading habit. Branches either cylindric or long green or hardened, checked back and spinescent, occasionally, especially flowering branches developing tendrils for support. Leaves simple, usually alternate. Flowers hermaphrodite or more or less diclinous, pentamerous to tetramerous, greenish to greenish-yellow to yellowish-white; sepals five to four; petals five to four alternating with sepals; stamens five opposite the petals, perigynous; pistil either free in center of receptacular cup or more or less fused with it and so semi-inferior, ovary typically three-celled becoming rarely four-celled with two to one atropous ovules in each cavity. Fruit of three indehiscent cocci, each enclosing a single albuminous seed with straight embryo imbedded in albumen.

Official drug	Parts used	Botanical origin	Habitat
Cascara Sagrada	Bark	Rhamnus Purshiana	Northern California to southwestern British America
Frangula.	Bark	Rhamnus Frangula	Europe
Rhamnus Cathartica N.F.	Fruit	Rhamnus cathartica	Asia and Africa

*Vitaceæ* or *Grape Family*.—Rarely tall herbaceous, usually shrubby and climbing, more rarely shrubby upright plants. Stems

rarely short more usually elongate, feeble, rather brittle, climbing by tendrils which represent modified inflorescence shoots. Leaves alternate, simple to lobed (either pinnately or more often palmately) to compound-pinnate or palmate. Perfect graded series of lanceo-



FIG. 170.—*Rhamnus frangula*—Branch. (Sayre.)

late leaves with pinnate veining to palmate veining; from pinnately veined to compound-pinnate; from palmately veined to compound-palmate. Stipules greenish to membranous or none. Flowers in racemes of compressed cymes, hermaphrodite or diclinous, nearly



always small, clustered, green to greenish-yellow or greenish-white, rarely otherwise; sepals five rarely four, small to minute (mere rim of receptacle) more or less persistent. Petals five, deciduous to caducous, typically distinct, in *Vitis* united by their tips into calypetroform corolla, so in June, as Grape Vine flowers expand, corolla splits at base into five lobes that separate below, being attached at tips, while whole becomes tumbled off by lengthening stamens. Pistil bicarpellate. Ovary two-celled, superior or at most sub-inferior. Ovules two to one, erect. Style short often more or less thickened with terminal, capitate, slightly two-lobed stigmas. Stamens equal to petals or sepals and opposite petals. Receptacle internal to stamens often expanded into nectariferous girdle or in *Vitis* into receptacular knobs alternating with stamens. Fruit a berry rarely six- to three-celled, typically two-celled and with two to one seeds in each cavity. Seeds like ovules, erect, with bony testa. Embryo small, imbedded at base of cartilaginous albumen.

Official drug	Part used	Botanical origin	Habitat
Vinum Xericum N.F.	Fermented juice of ripe fruit	<i>Vitis</i> species (cultivated)	Cultivated

**VIII. Order Malvales.**—*Sterculiaceæ* or *Cola Family*.—Rarely herbs, usually shrubs or tall, often heavy trees with soft wood and broad annual rings. The cambium in developing bast produces one, two, three, four, or five alternating layers of hard and soft bast which in some species of this as well as the *Tiliaceæ* family form long finger-like processes pushing out into the cortex. Leaves alternate, sometimes simple and pinnately veined or passing to palmately veined or palmately compound. Flowers hermaphrodite; sepals five, sometimes surrounded by bracteoles forming an epicalyx; petals usually five; stamens typically five hypogynous, opposite petals, distinct or slightly fused in monadelphous fashion (*Melochia*, *Waltheria*) or, stamens subdivided above into few or numerous staminal leaflets, anthers two-celled; pistil many to ten- to five- or four-carpelled; carpels apocarpous or more usually partially or completely united. Fruit either follicles, or fused to form a capsule of ten or more, frequently five dehiscent carpels or, carpels splitting asunder

into cocci or, becoming a woody capsular nut (*Theobroma*) or, rarely the fruit may become succulent. Seeds globose or subglobose



FIG. 171.—*Theobroma cacao*—Branch and fruit. (Sayre.)

and often provided with wings, arils or similar appendages; embryo straight, large and surrounded by scanty albumen.

Official drug	Part used	Botanical origin	Habitat
Oleum Theobromatis	Fixed oil	Theobroma Cacao	Tropical America
Cacao Præparatum N.F.	Prepared powder from roasted kernels of seeds	Theobroma Cacao and other species	Tropical America
Kola N.F.	Cotyledons	Cola acuminata and other species	Africa, West Indies

*Tiliaceæ* or *Linden Family*.—Shrubs or trees, rarely herbs, having stellate hairs on both stems and leaves. Leaves alternate, pinnately more rarely palmately veined, stipulate. Inflorescence cymose. Flowers hermaphrodite, more rarely by absorption more or less declinous; sepals and petals five each, more rarely four, sepals deciduous; stamens five opposite the petals or, as in *Sterculiaceæ*, five phalanges of stamens representing subdivided stamens (*Tilia*), pistil of ten to five or two syncarpous carpels; ovary superior. Fruit either a nut-like drupe or drupe, rarely baccate.

Unofficial drug	Part used	Botanical origin	Habitat
Tilia	Inflorescence	Tilia species	United States and Europe

*Malvaceæ* or *Mallow Family*.—Herbs in temperate regions (*Malva rotundifolia*, *Althæa officinalis*, etc.), occasionally shrubs in temperate regions (*Hibiscus Syriacus*, etc.), frequently shrubs or tall trees in the tropics. Stems as in *Sterculiaceæ* and *Tiliaceæ*, sometimes forming numerous layers of hard and soft bast. Leaves alternate and stipulate, ovate, ovate-cordate, orbicular or palmately compound; venation pinnate or palmate. Stems, roots and leaves contain mucilage cells. Inflorescence a raceme or fascicle of cymes. Flowers regular, pentamerous; calyx green, of five aposepalous sepals but frequently surrounded outside by an epicalyx. Both calyx and epicalyx are persistent. Corolla of five petals varying in color which are more or less fused with stamens at their bases; stamens monadelphous and forming an upright column enclosing the styles; anthers one-celled, dehiscing transversely; pollen grains echinate; pistil loosely or strongly syncarpous, rarely sub-apocarpous of thirty to five carpels. Fruit either a set of cocci, follicles or a capsule (*Gossypium*). Seeds albuminous with oily and mucilaginous albumen.



FIG. 172.—*Gossypium herbaceum*—Branch. (Sayre.)

Official drug	Part used	Botanical origin	Habitat
Althæa	Root (peeled)	<i>Althæa officinalis</i>	Europe and Asia
Althææ Folia N.F.	Leaves	<i>Althæa officinalis</i>	Europe and Asia
Gossypii Cortex N.F.	Bark of root	Cultivated varieties of:	
		Gossypium herbaceum	Arabia, United States, East Indies
		Gossypium Barbadense	United States and Africa
Gossypium Purificatum	Hairs of seed	Gossypium arboreum	Egypt, Arabia and India
		Cultivated varieties of Gossypium herbaceum	
Oleum Gossypii Seminis	Fixed oil from seeds	Cultivated varieties of Gossypium species	
		United States, Asia, Africa and South America	
<b>Unofficial</b>			
Althææ Flores	Flowers	<i>Althæa rosea</i>	Europe

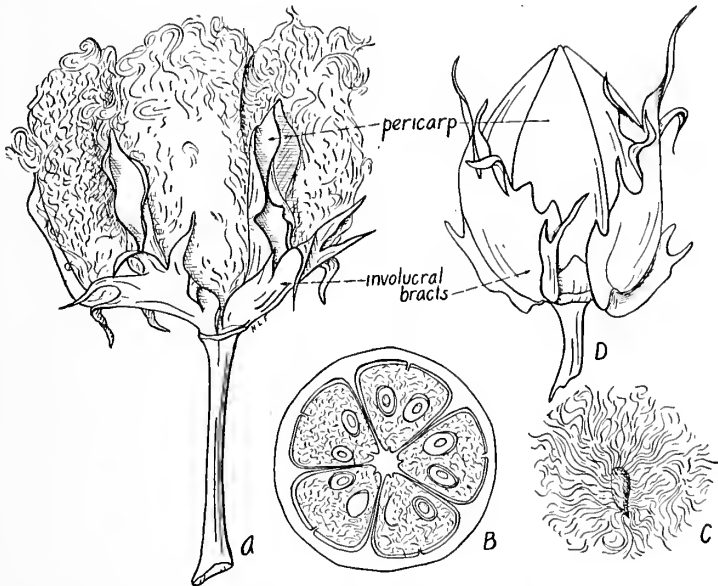


FIG. 173.—Upland cotton (*Gossypium hirsutum*). A, mature boll opened out; B, cross-section of young boll; C, single seed with fibers; D, young boll. (Robbins.)

**XIX. Order Parietales** (Ovaries of flowers have parietal placentas).—*Theaceæ* or *Tea Family* (*Ternstræmiaceæ*, *Cammeliaceæ*).—Evergreen shrubs or low branching or tall, often heavy trees with watery juice. Leaves for the most part alternate, evergreen, often leathery, sometimes membranous; stipules either bud scales and caducous or often absent; leaf margins sinuate or serrate (*Thea*). Inflorescence a raceme becoming by condensation terminal, one-flowered. Flowers regular, perfect, pentamerous; sepals five, rarely four to three, deciduous, occasionally subtended by bracteolar scales; petals five, brittle and succulent varying from greenish-white or greenish-yellow through yellow to white or, from whitish pink to pink, scarlet, crimson, very rarely a tendency toward purple; stamens typically five but, as they grow, they subdivide into staminal leaflets so that in their mature condition they are apparently indefinite and mono- to polyadelphous; stamens inserted hypogynously or perigynously and opposite the petals; pistil of typically five syncarpous carpels but reduced in some species to four to three or two. Fruit usually a capsule (*Thea*), five- to three-celled, dehiscing longitudinally, more rarely a fleshy, semi-baccate, semi-drupaceous indehiscent fruit. Seeds with scanty or no albumen and often attached to inner angle of cells by projecting spongy placentæ.

Official drug	Part used	Botanical origin	Habitat
Caffeina	Feebly basic substance	<i>Thea sinensis</i>	Eastern Asia
<b>Unofficial</b>			
<i>Thea</i>	Leaves	<i>Thea sinensis</i> var. <i>Bohea</i> and <i>viridis</i>	Eastern Asia

*Guttiferæ* or *Gamboge Family*.—Tropical trees (*Garcinia*), rarely shrubs, containing resinous principles in resin canals found in cortex and pith. Leaves opposite, coriaceous. Flowers diœcious, generally pentamerous or tetramerous with usually five stamens which are subdivided. Fruit a berry (*Garcinia Hanburyi*), drupe or capsule. Seeds generally large; embryo large to huge often with enlarged radicle and reduced or absorbed cotyledons.

Official drug	Part used	Botanical origin	Habitat
Cambogia	Gum resin	<i>Garcinia Hanburyi</i>	{ Malabar coast and Travancore

*Canellaceæ Family*.—Trees the bark of which contains aromatic principles. Leaves alternate, pellucid-punctate. Flowers regular, golden-yellow, and arranged in terminal or axillary cymes. Fruit a berry containing two to many seeds with oily and fleshy albumen.

Official drug	Part used	Botanical origin	Habitat
Canella N.F.	Inner bark	Canella Winterana	{ Florida and West Indies

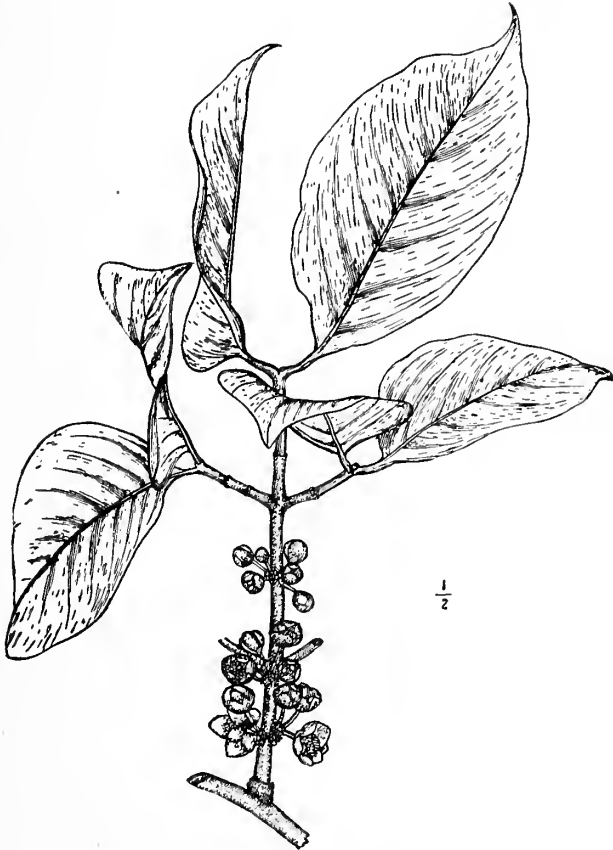


FIG. 174.—*Garcinia hanburii*—Branch. (Sayre.)

*Bixaceæ Family*.—Tropical shrubs or trees. Leaves alternate, simple with minute or no stipules. Flowers hermaphrodite or uni-

sexual, regular; stamens hypogynous, mostly indefinite with anthers opening by slits, rarely by one or two apical pores (*Bixa*). Fruit fleshy or dry. Seeds with fleshy albumen and sometimes covered with a fleshy arillus (*Bixa Orellana*).

Unofficial drug	Part used	Botanical origin	Habitat
Annatto	Coloring matter	<i>Bixa Orellana</i>	Tropical America and Madagascar
Chaulmoogra oil	Fixed oil from seeds	<i>Gynocardia odorata</i>	

*Violaceæ* or *Violet Family*.—Herbs or shrub. Stems upright, rarely creeping, spreading or acaulescent. Leaves either cauline or radical, stipulate, alternate, simple to pinnatifid or palmate. Flowers pentamerous, regular or irregular (*Viola*). Fruit a loculicidally dehiscent capsule (*Viola*) rarely baccate. Seeds albuminous.

Unofficial drug	Part used	Botanical origin	Habitat
<i>Viola</i>	Entire herb	<i>Viola tricolor</i>	Temperate regions

*Turneraceæ* or *Damiana Family*.—Tropical herbs, shrubs or trees. Leaves alternate, simple, petioled, exstipulate. Flowers perfect, regular, axillary, pentamerous with one-celled ovary. Fruit a capsule with three valves. Seeds strophiolate with albuminous embryo.

Official drug	Part used	Botanical origin	Habitat
Damiana N.F.	Leaves	{ <i>Turnera diffusa</i> <i>Turnera</i> <i>aphrodisiaca</i>	{ Lower California and Mexico

*Passifloraceæ* or *Passion Flower Family*.—Herbaceous or woody vines climbing by tendrils. Leaves alternate, simple, entire, lobed or compound. Flowers perfect or imperfect, solitary; peduncles jointed at the flower; perianth petaloid with urceolate or tubular tube and four to five or eight to ten partite and two-seriate limb, the throat usually crowned by one or more series of subulate filaments which are frequently colored; gynophore elongating supporting the stamens and pistil. Fruit a one-celled berry (*Passiflora*) or three- to five-valved dehiscent capsule containing numerous seeds.

Official drug	Part used	Botanical origin	Habitat
<i>Passiflora</i> N.F.	Entire herb	<i>Passiflora incarnata</i>	United States



*Caricaceæ* or *Papaw Family*.—A family of latex-containing trees composed of two genera indigenous to tropical America. Of chief pharmaceutical interest is the species *Carica Papaya*, the Papaw or Melon tree, the fruit of which yields Papain, a valuable digestive ferment. This plant is a tree about 20 feet high which bears at its summit a cluster of deeply lobed petiolate leaves and diœcious flowers. The fruit is a berry, the size of one's head and contains an acrid milky juice from which papain can be precipitated by the addition of alcohol.

*Cistaceæ* or *Rock Rose Family*.—Herbs or shrubs whose stem and branches are often glandular, pubescent or tomentose, with simple or stellate trichomes. Leaves simple, entire, the lower ones opposite, upper alternate. Flowers perfect, regular, terminal, and solitary or in cymes or unilateral racemes; sepals five, the two external ones often bractiform or wanting; petals five (*Helianthemum*) rarely three or none (*Lechea*); stamens hypogynous, indefinite; carpels three to five, ovary free, one-celled. Fruit a one-celled three- to five-valved capsule.

Official drug	Part used	Botanical origin	Habitat
Helianthemum N.F.	Herb	Helianthemum canadense	Eastern United States

**XX. Order Opuntiales.**—*Cactaceæ* or *Cactus Family*.—Herbaceous rarely arborescent (*Cereus giganteus*) more or less succulent plants living in warm dry (*Peireskia*) usually desert situations, rarely becoming epiphytic and correspondingly modified. Stems accordingly varying from elongate, slightly enlarged, green (*Peireskia*) to flattened (*Cereus* and *Opuntia*) to condensed (*Echinocactus*, *Echinocereus*, etc.) to greatly condensed (*Mamillaria*). Leaves alternate, stipulate or exstipulate, enlarged and more or less fleshy (*Peireskia*) becoming reduced green and semicircular (*Opuntia*) or modified into spines or wholly absorbed. Flowers, regular, solitary or fascicled in axils of leaves; sepals five; petals similar to sepals, petaloid, small to much enlarged, in color varying from yellow to white or from yellow to yellowish-pink, pink, scarlet or crimson; stamens indefinite inserted at varying levels in the throat of a greatly expanded upgrown receptacle; pistil generally tricarpeillary; ovary inferior, often

deeply sunk in upgrown receptacular part; style thread-like, divided above into as many stigmas as carpels. Fruit a receptacular berry enclosing numerous small seeds. Seeds exalbuminous.

Official drug	Part used	Botanical origin	Habitat
Cactus Grandiflorus N.F.	Fresh succulent stems	Cactus grandiflorus ( <i>Cereus grandiflorus</i> )	} Tropical America



FIG. 175.—*Daphne mezereum*—Fruiting branch and flowers. (Sayre.)

**XXI. Order Myrtales (Myrtifloræ).**—*Thymeleaceæ* or *Mezereum* Family.—Shrubs (*Daphne Mezereum*) or low trees, usually of branching habit, the stems developing long tenacious bast fibers. Leaves

alternate, rarely, opposite, coriaceous, simple, varying from lanceolate to ovate. Inflorescence a condensed raceme or spike. Flowers perfect, polygamous or diœcious, small with calyx alone of the perianth parts developed. This is crimson-purple in *Daphne Mezereum*. Sepals usually fused to form a tube or cup-shaped perianth. Stamens usually eight in two rows of four longer and four shorter (*Daphne Mezereum*) inserted on the calyx tube. Pistil monocarpellary; ovary superior mostly one-celled with a single pendulous ovule. Fruit a nut, drupe or berry (*Daphne*).

Official drug	Part used	Botanical origin	Habitat
Mezereum	Bark	{ <i>Daphne Mezereum</i> <i>Daphne Gnidium</i> <i>Daphne Laureola</i>	Europe and Asia



FIG. 176.—*Punica granatum*—Branch with flowers. (Sayre.)

*Punicaceæ* (*Lythraceæ*) or *Pomegranate Family*.—Herbs (*Cuphea*), shrubs (*Decadon*) or low trees (*Punica*). Leaves either alternate, opposite (*Punica*) or whorled, simple, usually lanceolate to ovate, entire often glandular and viscous. Inflorescence a raceme, spike, or condensed cyme. Flowers perfect usually regular but pass more or less to irregular, sometimes very irregular as in genus *Cuphea*;

sepals five to four, more or less fused below in themselves and with calyx tube; petals commonly five, often frilled or crumpled, inserted on the mouth of the calyx tube; stamens fifteen, ten or five in alternate rows of five each, inserted hypogynously or perigynously; pistil six-, five-, four-, two-, rarely one-carpeled with as many cavities in the ovary and numerous small ovules; style elongate with pointed or knobbed stigma. Flowers of *Punica granatum* are scarlet in color. Fruit a baccate capsule (*Punica granatum*) or capsule dehiscing longitudinally or transversely. Seeds exalbuminous.

Official drug	Part used	Botanical origin	Habitat
Granatum	Bark	Punica Granatum	India
<b>Unofficial</b>			
Granati Fructus Cortex	Rind of fruit	Punica Granatum	India

*Myrtaceæ* or *Myrtle Family*.—Rarely herbs (*Careya*) mostly shrubs or trees, some being the tallest trees known (*Eucalyptus*). Stems often tend to develop cork in flakes which separate much as in the Buttonwoods. Leaves rarely alternate nearly always opposite, entire often glistening, subcoriaceous to coriaceous (*Eucalyptus*, *Pimenta*, etc.), frequently edge-on in position upon branches. Inflorescence cymose, at times forming scorpioid cymes becoming condensed into small fascicles, or each cyme condensing into a solitary flower.

Flowers regular or very rarely irregular from the lop-sided development of the stamens. Symmetry rarely hexamerous, typically pentamerous, not infrequently reduced to tetramerous (*Clove*); sepals five, six or four, aposepalous, or synsepalous at base, superior, and inserted around the edge of an expanded, upgrown receptacular disc, varying from green and more or less expanded to short thick fleshy (*Clove*) or reduced to teeth (*Eucalyptus*); petals equal in number to the sepals, more or less petaloid and enlarged, rarely reduced and wanting, varying in color from green through greenish-yellow to white (*Eugenia* species) or from whitish to pink, scarlet, crimson, purple and blue, petals sometimes synpetalous and cup-like, detaching as the flower opens; stamens usually indefinite and epigynous, varying in the color of their filaments as do the



FIG. 177.—*Eucalyptus globulus*—Branch. (Sayre.)

petals; pistil rarely of ten to six carpels usually of five, not infrequently as in Clove of four carpels; ovary inferior or semi-inferior, as many-celled as there are carpels and with central placentation;



FIG. 178.—*Eugenia aromatica*. (Sayre.)

style elongate; stigma undivided. Fruit either a hard, woody indehiscent nut (Brazil Nut), a capsule dehiscing at apex (*Eucalyptus*) or berry (*Eugenia*). Seeds exalbuminous.

Official drug	Part used	Botanical origin	Habitat
Eucalyptus	Leaves	<i>Eucalyptus globulus</i>	Australia, Tasmania
Eucalyptol	Organic oxide	<i>Eucalyptus globulus</i>	
Caryophyllus	Flower buds	<i>Eugenia aromatica</i>	Molucca Islands
Eugenol	Aromatic phenol	<i>Eugenia aromatica</i>	
Pimenta N.F.	Fruit	<i>Pimenta officinalis</i>	
Oleum Cajuputi	Volatile oil from leaves and twigs	<i>Melaleuca</i> <i>Leucadendron</i>	West Indies, Central America, Mexico East Indies
<b>Unofficial</b>			
Myrcia	Volatile oil and leaves	<i>Myrcia acris</i>	West Indies
Eucalyptus Kino	Inspissated juice	<i>Eucalyptus rostrata</i> and other species	Australia

*Combretaceæ* or *Myrobalans* Family.—Mostly tropical shrubs and trees containing considerable tannin. Leaves exstipulate, alternate or opposite, simple, pinnately veined, entire or toothed. Inflorescence a raceme, spike or head. Flowers regular, perfect or imperfect. Fruit a drupe, frequently longitudinally winged containing a single seed.

Unofficial drug	Part used	Botanical origin	Habitat
Combretum	Leaves	<i>Combretum</i> <i>sundaicum</i>	Sumatra

**XXII. Order Umbellales or Umbellifloræ.**—*Araliaceæ* or *Ginseng* Family.—Herbs (*Panax quinquefolium*, *Hedera Helix*, *Aralia nudicaulis*, etc.), undershrubs (*Aralia hispida*, etc.), shrubs (*Fatsia horrida*), or trees (*Aralia spinosa*) with stems which are more or less hollow along internodes and solid at nodes. Leaves alternate, varying from simple to trifoliolate or to multipinnate (tropical *Aralias*) or passing by telescoping into compound-palmate. Leaves serrate margined and along with stem they develop volatile oil, resin and gum contents in secretion reservoirs. Inflorescence varying from a raceme of umbels to a raceme and even to condensed racemose umbels. Flowers regular, generally pentamerous, small, generally inconspicuous, green, greenish-yellow to rarely white, usually hermaphrodite but sometimes polygamous or diœcious; sepals

five, rarely four; petals five, rarely four, often greenish to greenish-yellow, occasionally white, seldom pink in color; stamens varying from indefinite to ten to commonly five, opposite sepals, and, like sepals, epigynous in insertion; anthers versatile; pistil occasionally fifteen- to ten-, usually five-carpellate; ovary as many celled with one or rarely two pendulous ovules in each cavity; styles distinct ending in knob-shaped stigmas. Fruit a berry. Seeds albuminous.

Official drug	Part used	Botanical origin	Habitat
Aralia N.F.	Rhizome and roots	Aralia racemosa	Eastern United States and Canada
<b>Unofficial</b>			
Aralia Nudicaulis	Rhizome	Aralia nudicaulis	Eastern United States and Canada
Aralia Spinosa	Bark	Aralia spinosa	Eastern United States
Ginseng	Root	Panax quinquefolium	North America
Panax Repens	Rhizome	Panax repens	Japan

*Umbelliferae or Parsley Family.*—Herbs, rarely shrubs, often of rapid growth, and with upright fistular (hollow at internodes, solid at nodes) often grooved and ridged stems. Leaves alternate, compound and usually much divided, exstipulate, but with expanded sheathing and flattened leaf base (Pericladium), that ensheathes the stem. Inflorescence a simple or often compound umbel surrounded by an involucre of bracts or of bracteoles. Flowers small, pentamerous, with inferior ovary and superior floral parts. Sepals minute, tooth-like, inserted above inferior ovary, or absorbed. Petals small, usually yellow to white, rarely pink to purple, distinct, each with inflexed tip. Stamens five, epigynous, inserted below a nectariferous, epigynous disc, incurved in bud. Carpels two fused into bicarpellate pistil. Ovary two-celled, with one pendulous ovule in each cell, ovarian wall traversed by oleoresin canals; styles two distinct above the nectar disc or stylopod. Fruit a dry, splitting fruit or cremocarp, that splits lengthwise into two mericarps which hang for a time by a forked carpophore. Seeds single in each mericarp, albuminous.



Official drug	Part used	Botanical origin	Habitat
Anisum	Ripe fruit	Pimpinella Anisum	Asia Minor, Egypt and Greece.
Anethol N.F.	Methyl ether of para-pro-phenyl phenol	Pimpinella Anisum	
Fœniculum		Fœniculum vulgare	
Fœniculum	Nearly ripe fruit	Fœniculum vulgare	Mediterranean region
Sumbul	Rhizome and roots	Ferula Sumbul	Turkestan
Carum	Fruit	Carum Carvi	Europe, Asia
Conium N.F.	Unripe fruit	Conium maculatum	Europe
Asafœtida	Gum resin	Ferula foetida, F. Asafœtida, etc.	Persia and Afghanistan
Coriandrum	Ripe fruit	Coriandrum sativum	Mediterranean and Caucasian regions
Petroselinum	Ripe fruit	Petroselinum sativum	Southern Europe Asia Minor
Petroselini Radix N.F.	Root	Petroselinum sativum	Southern Europe, Asia Minor
Angelicæ Fructus N.F.	Ripe fruit	Angelica Archangelica and other species of Angelica	Northern Europe and Siberia
Angelicæ Radix N.F.	Rhizome and roots	Angelica atropurpurea and other species of Angelica	United States and Canada
Apii Fructus N.F.	Ripe fruit	Apium graveolens	England
<b>Unofficial</b>			
Imperatoria	Root	Imperatoria Ostruthium	Europe
Pimpinella	Roots	{ Pimpinella Saxifraga Pimpinella magna }	Central Europe
Ammoniacum	Gum-resin	Dorema Ammoniacum	
Galbanum	Gum-resin	Ferula galbaniflua	Persia and Afghanistan
Levisticum	Root	Levisticum officinale	Europe

*Cornaceæ* or *Dogwood Family*.—Herbs (*Cornus canadensis*, etc.), shrubs (*Cornus sanguinea*, etc.) or trees (*Cornus florida*, *Nyssa sylvatica*, etc.). Leaves simple, alternate (Sour Gum), or opposite (Dogwoods). Inflorescence an umbel or head, the whole being

surrounded by an enlarged and more or less petaloid involucre. Flowers regular, rarely pentamerous, more frequently tetramerous; sepals usually four, small tooth-like or absorbed; petals usually four, small, greenish to yellowish to white (*Cornus florida*), rarely pink or crimson; stamens four or five alternate to the petals and inserted with the sepals and petals epigynously around and between the nectar disc; pistil syncarpous, bicarpellate, rarely tricarpellate; ovary as many celled with one pendulous ovule in each cavity; style usually simple, ending in rounded or slightly bilobed stigma. Fruit a two-seeded drupe. Seeds albuminous.

Official drug	Part used	Botanical origin	Habitat
Cornus N.F.	Bark of root	Cornus florida	Eastern United States and Canada

SUB-CLASS B.—SYMPETALE (GAMOPETALE OR METACHLAMYPDEÆ)

A division of dicotyledonous plants in which the flowers possess both calyx and corolla, the latter with petals more or less united into one piece.

**I. Order Ericales.**—*Ericaceæ* or *Heath Family*.—Sub-herbaceous (*Chimaphila*), suffruticose (*Erica*), fruticose (*Azaleas*, *Kalmias*, etc.), rarely sub-arborescent (*Arbutus unedo* or Strawberry Tree) plants. Roots fibrous often saprophytically associated, rarely tuberous or more or less enlarged. Stem upright, ascending or creeping, more or less woody, rarely through saprophytic connection becoming soft, annual and pale above ground (*Monotropa uniflora*). Leaves alternate, simple, entire, exstipulate, rarely soft, delicate, herbaceous (*Azaleas*), usually leathery to wiry and evergreen, more rarely (*Pterospora*, *Monotropa*, etc.) becoming greenish-blue, bluish-yellow, yellowish-white to white and correspondingly saprophytic. Inflorescence typically a raceme (*Pyrola*, *Andromeda*, *Gaylussacia*, *Erica*, *Arctostaphylos Uva Ursi*, etc.) but raceme condensed into a racemose umbel (*Azalea*, etc.) or further reduced to a few flowers or, in the degraded saprophytic condition to one flower (*Monotropa uniflora*). Flowers regular, passing to irregular (*Rhododendron*), pentamerous or tetramerous; sepals five to four rarely fewer, apotosepalous, usually green, sometimes brightly petaloid; petals

five more rarely four, slightly to deeply synpetalous, cup-shaped (*Kalmia*) to urceolate (*Arctostaphylos Andromeda*, etc.), yellow to white or through yellow pink to scarlet to crimson to crimson-purple; stamens ten to eight in two circles of five to four each, becoming by absorption of inner circle five to four only, hypogynous, epipetalous or epigynous; anthers two-celled, dehiscing by apical



FIG. 179.—*Arctostaphylos uva ursi*—Branch, flower, and fruiting branch. (Sayre.)

pores (*Arctostaphylos*) or apical slits; pollen sometimes agglutinated into long viscous threads; pistil five- to four-, rarely six- to eight- carpelled, superior, rarely semi-inferior to inferior (*Vaccineæ*); ovary as many celled as there are carpels; style elongated, filiform, usually five- to four lobed. Fruit a capsule (*Trailing Arbutus*), berry (*Vaccinium*) or false drupe (*Gaultheria*). Seeds small, anatropous.

Official drug	Part used	Botanical origin	Habitat
Chimaphila N.F.	Leaves	Chimaphila umbellata	United States, Canada, North- ern Europe and Asia
Uva Ursi	Leaves	Arctostaphylos Uva Ursi	
Methylis Salicylas	Volatile oil	Gaultheria procumbens	Northern United States and Canada, Europe and Asia
<b>Unofficial</b> Gaultheria	Leaves	Gaultheria procumbens	United States and Canada

**II. Order Ebenales.**—*Sapotaceæ* or *Star Apple Family*.—Tropical shrubs or trees (*Palaquium*) characterized by the presence of laticiferous sacs in the pith and cortex of the stems and adjoining the veins of the leaves. Leaves alternate, exstipulate, evergreen and coriaceous. Flowers perfect, large and axillary. Fruit a berry (*Palaquium*) rarely a capsule (*Ponteria*).

Official drug	Part used	Botanical origin	Habitat
Gutta Percha N.F.	Purified coagu- lated milky exudate	Various species of Palaquium	Indo-China and East Indies

*Styracæ* or *Benzoin Family*.—Shrubs or low trees. Leaves alternate to opposite, entire, often acuminate. Flowers hermaphrodite, regular, rarely sub-irregular, either in condensed fascicles or solitary in the axils of the leaves; sepals and petals typically five each; corolla often white, rarely pinkish or yellowish; stamens many to four or two, perigynous or sub-hypogynous; pistil bicarpillary or four to five carpellate. Fruit either fleshy or dry, often winged and rarely as many-celled as there are carpels.

Official drug	Part used	Botanical origin	Habitat
Benzoinum	Balsamic resin	Styrax Benzoin and other species	East Indies

**III. Order Contortæ.**—*Oleaceæ* or *Olive Family*.—Shrubs (*Forsythia*, *Chionanthus*, *Syringa*, etc.) or trees (*Fraxinus*, *Olea*, etc.) with stems possessing close white wood, and slightly swollen or enlarged

nodes. Leaves opposite, decussate, simple, rarely pinnately compound (Ash). Inflorescence dichesial or scorpioid cymes but tending constantly toward condensation and so in the Lilac, the inflorescence becomes a clustered raceme of cymes (thyrsus). Flowers regular, pentamerous or tetramerous; sepals small, green, rarely petaloid, synsepalous; petals synpetalous, elongated into a narrow tube, expanding above into a stellate limb; stamens very rarely five, rarely four to three, nearly always two, epipetalous and high set on corolla tube; pistil bicarpellate, rarely of three to four carpels; ovary two-celled with two to one pendulous ovules in each cavity. Fruit either a capsule (Lilac), drupe (Olive), berry (Privet) or a winged indehiscent akene (Ash). Seeds with moderate to scanty albumen becoming occasionally exalbuminous.

Official drug	Part used	Botanical origin	Habitat
Manna	Dried saccharine exudate	Fraxinus Ornus	Southern Europe
Oleum Olivæ	Fixed oil	Olea Europæa	Southern Europe, Algeria, Asia
Chionanthus N.F.	Bark of root	Chionanthus virginica	Southern United States
Fraxinus N.F.	Bark	Fraxinus Americana	Northern United States and Canada

*Loganiaceæ* or *Logania* Family.—Herbs (*Spigelia*, etc.), woody vines (*Gelsemium*, etc.) or trees (*Strychnos Nux Vomica*, etc.) with a bitter juice usually containing alkaloids. Stem, rarely herbaceous usually woody, often long climbing and rope-like (*Gelsemium*), usually with a bicollateral bundle system. Leaves opposite, stipulate or exstipulate. Inflorescence racemose or cymose (*Spigelia* (scorpioid cyme), *Strychnos*), sometimes condensed into solitary, axillary flowers. Flowers perfect, usually regular; calyx gamosepalous; corolla gamopetalous, hypogynous, rotate, campanulate or infundibuliform; stamens inserted on the corolla tube or throat and with thread-like filaments; ovary superior, two-celled; style elongate with bifid stigma; ovules numerous. Fruit usually a capsule, septicidally dehiscent (*Gelsemium sempervirens*) or loculicidally dehiscent (*Spigelia marilandica*), sometimes a berry (*Strychnos Nux Vomica*) or drupe. Seeds numerous or solitary, sometimes winged.



FIG. 180.—*Strychnos nux vomica*—Flowering branch and seeds. (Sayre.)

Official drug	Part used	Botanical origin	Habitat
Nux Vomica	Seeds	<i>Strychnos Nux Vomica</i>	East Indies
Gelsemium	Rhizome and roots	<i>Gelsemium sempervirens</i>	Southern United States
Spigelia	Rhizome and roots	<i>Spigelia marilandica</i>	Southern United States
Ignatia N.F.	Seeds	<i>Strychnos Ignatii</i>	Philippine Islands

*Gentianiaceæ* or *Gentian Family*.—Herbs often low-growing. Roots and short stems sometimes more or less thickened (*Gentiana lutea*). Leaves opposite, decussate, entire, exstipulate. Inflorescence cymose



FIG. 181.—*Gentiana lutea*—Flowering head and dissected flower. (Sayre.)

(*Gentiana lutea*) or condensing to a single solitary terminal flower (*Gentiana verna*, *G. acaulis*, etc.) Flowers regular, perfect, pentamerous or tetramerous, sepals five to four, green, more or less synse-

palous, not infrequently everted or reflexed, corolla of five, rarely four petals, more or less synpetalous, in shape passing from open-stellate as in *Gentiana lutea* through many stages of connation to long-tubed as in *Gentiana acaulis*; stamens five, epipetalous; pistil bicarpellate; ovary one-celled or incompletely two-celled; style more or less elongated with bilobed to divided stigma. Fruit a capsule. Seeds albuminous.

Official drug	Part used	Botanical origin	Habitat
Gentiana	Rhizome and roots	<i>Gentiana lutea</i>	Europe and Asia Minor
Chirata N. F.	Entire plant	<i>Swertia Chirayita</i>	Northern India
Menyanthes N.F.	Leaves	<i>Menyanthes trifoliata</i>	Europe and Asia
Centaurium N.F.	Flowering plant	<i>Erythræa Centaurium</i>	Europe
<b>Unofficial</b>			
Sabatia	Herb	<i>Sabatia angularis</i>	Eastern United States and Canada

*Apocynaceæ* or *Dog Bane Family*.—Herbs, rarely shrubs not infrequently clambering or climbing in habit (*Allamanda*). Stem and branches show bicollateral bundles. Stem, leaves and flowers have latex tubes which ramify through the cortex and mesophyll tissues. Leaves alternate, opposite or verticillate, simple, entire, deciduous or evergreen. Inflorescence cymose. Flowers regular, pentamerous, rarely tetramerous; sepals five, gamosepalous, green, rarely subpetaloid to petaloid; petals five, slightly to deeply gamopetalous, in shape varying from open tubular, stellate, to elongate tubular to elongate funnel-shaped, in color varying from greenish-yellow to white or from yellow to yellow-red to crimson to crimson-purple to nearly purple-blue; stamens five, epipetalous; pistil usually bicarpellate; ovary two-celled with central placentation; style more or less elongate with terminal brush of hairs, knobbed or multifid; stigma circular band or circular spur beneath terminal style swelling. Fruit two follicles (*Apocynum*, etc.), a berry, drupe, or capsule. Seeds flattened, frequently hairy, albuminous.





FIG. 182.—*Strophanthus hispidus*—Branch and seed with comose awn. (Sayre.)

Official drug	Part used	Botanical origin	Habitat
Strophanthus	Seeds (deprived of awn)	<ul style="list-style-type: none"> <li>Strophanthus</li> <li>Kombe</li> <li>Strophanthus hispidus</li> </ul>	} Africa
Strophanthin	Glucoside	Strophanthus hispidus	
Apocynum N.F.	Rhizome and roots	Apocynum cannabinum	United States and Canada
Aspidosperma	Bark	Aspidosperma Quebracho blanco	Central and South America

*Asclepiadaceæ* or *Milkweed Family*.—Herbs or shrubs containing a milky juice, many species yielding rubber. Leaves entire, more or less fleshy, sometimes verticillate. Inflorescence usually a dichesial or scorpioid cyme. Flowers regular, pentamerous; sepals woolly, small, synsepalous; petals five, rarely four, synpetalous, elongated into awls; the corolla varying in shape from stellate to campanulate and in color from pale green to yellow, to greenish-brown, chocolate, or from white to yellow, to scarlet, to crimson, to purple, to blue; stamens five, epipetalous, fused in relation forming a cylindrical swollen mass around the central pistil; filaments flattened and furnished with a crown having various appendages; anthers two-celled, each cell containing a pollen mass (pollinium), adhering to the glandular prominences of the stigma; pistil bicarpellate, superior. Fruit typically two dry follicles (*Asclepias*), rarely becoming succulent or bladderly. Seeds numerous, compressed, imbricate with a comose appendage.

Official drug	Part used	Botanical origin	Habitat
Asclepias N.F.	Roots	<i>Asclepias tuberosa</i>	United States
Condurango N.F.	Bark	<i>Marsdenia</i> Condurango	Peru and Ecuador

**IV. Order Contortæ or Polemoniales.**—*Convolvulaceæ* or *Morning-glory Family*.—Frequently herbaceous, more rarely sub-woody, woody, perennial climbing plants with underground parts sometimes swollen into tuberous roots (Jalap, Sweet Potato, Wild Man of the Earth). Stems rarely short, upright or tufted, usually elongate and circumnutating in action. Vascular bundles frequently bicollateral. Leaves alternate, simple, exstipulate, varying from cordate to cordate-sagittal, to broad reniform to reniform, palmately lobed to palmatifid to palmately compound (*Ipomœa* shows all these transitions). Stem and leaves frequently contain a dull, viscous, watery to milky-white juice. Inflorescence a scorpioid cyme becoming reduced in some forms to a solitary flower. Flowers pentamerous; sepals five, green, gamosepalous; corolla varying in shape from rotate to funnel-like with expanded mouth, in color from greenish-yellow to white or through yellowish-pink to scarlet, crimson, purple or blue; stamens five, often with the bases of the fila-

ments expanded; pistil bicarpellate; ovary two-celled, superior, often surrounded by a nectar girdle; style filiform with bilobed or bifid stigma. Fruit usually a capsule (*Exogonium*, etc.), dehiscent septifragally, rarely a berry. Seeds scantily albuminous to exalbuminous.



FIG. 183.—*Convolvulus scammonia*—Branch. (Sayre.)

Official drug	Part used	Botanical origin	Habitat
Jalapa	Tuberous root	<i>Exogonium Purga</i>	Mexico
Scammoniae Radix	Root	<i>Convolvulus Scammonia</i>	} Asia Minor, Greece, Syria
<b>Unofficial</b>			
Male Jalap	Root	<i>Ipomœa orizabensis</i>	Mexico
Tampico Jalap	Root	<i>Ipomœa simulans</i>	Mexico
Wild Jalap	Root	<i>Ipomœa pandurata</i>	United States
Turpeth Root	Root	<i>Operculina Turpethum</i>	East Indies

*Hydrophyllaceæ* or *Water Leaf Family*.—Annual, herbaceous, rarely perennial woody plants whose stems, branches, leaves and sepals are often viscous and glandular hairy. Leaves alternate, exstipulate, from simple linear to pinnatipartite to pinnate. Inflorescence rarely expanded, usually scorpioid cymes. Flowers small to large, funnel-form in *Eriodictyon californicum*; sepals five, green; petals five, regular; corolla varying from small stellate with slightly fused petals to large rotate, campanulate or tubular, in color varying from greenish-white or yellow to rarely white, often pink, purple or blue; stamens five, rarely with alternate staminodes; pistil bicarpellate. Fruit a two-celled capsule dehiscing usually septicidally.

Official drug	Part used	Botanical origin	Habitat
Eriodictyon	Leaves	Eriodictyon californicum	California and New Mexico

*Borraginaceæ* or *Borage Family*.—Herbaceous (*Borragineæ* sub-family) or shrubby (*Heliotropeæ* sub-family), plants forming a primary root and a single or often branched shoots. Leaves often divisible into expanded, sometimes large basal and alternate scattered cauline leaves. Each of these simple, exstipulate, often hairy, rarely glabrous. Inflorescence a raceme of dichesial or scorpioid cymes, at times condensed into a dichesium of scorpioids or a simple scorpioid cyme. Flowers pentamerous, regular, passing to slight or marked irregularity (*Echium*); sepals five; green, slightly or deeply gamosepalous, often hairy; petals five, the corolla varying in shape from rotate with shallow tube (*Myosotis* and *Borage*), to tubular (*Symphytum*), to funnel-shaped in most species, in color, all transitions frequently purple-blue to blue; stamens five; pistil bicarpellate, syncarpous, embryologically two-celled with two ovules in each cavity, but dorsal ingrowths divide ovary by time of flowering into four cells with one ovule in each cavity; style gynobasic. Fruit typically four-nutlets. Seeds solitary in each cavity and either scantily albuminous (*Heliotropeæ*) or exalbuminous (*Borragineæ*).

Unofficial	Part used	Botanical origin	Habitat
Symphytum (Comfrey)	Root	Symphytum officinale	Europe and United States
Cynoglossum (Hound's tongue)	Herb and root	Cynoglossum officinale	United States

*Solanaceæ* or *Nightshade Family*.—Stem herbaceous rarely shrubby or arborescent, frequently with bicollateral bundles. Leaves alternate, exstipulate, entire, or more or less lobed, rarely compound; often glandular-hairy. Flowers in cymes; regular or rarely irregular



FIG. 184.—*Atropa belladonna*—Branch. (Sayre.)

(*Petunia*, *Tobacco* sps.), pentamerous, perfect, synphyllous; sepals green (rarely petaloid), rotate to tubular, usually persistent and accrescent; petals rotate (*Solanum*), to tubular (*Atropa*), to funnel-shaped (*Tobacco*), and so (1) open to all comers, or (2) to bees or

wasps, or (3) to butterflies, moths; color, greenish-yellow, or greenish-white, to white, to pink, crimson, purple, rarely blue; stamens five, epipetalous, hypogynous, along with style usually forming nectar glands. Filaments short to long, anthers dehiscing longitudinally or by apical pores; pistil bicarpellate, syncarpous, with



FIG. 185.—*Hyoscyamus niger*—Flowering branch. (Sayre.)

or without nectar girdle, superior ovary, two-celled with central placentation, ovules numerous, style more or less elongate with bilobed or bifid stigma. Fruit, a capsule (Tobacco, Thornapple, Henbane) dehiscing longitudinally or transversely; or a berry (potato, egg-plant, tomato, red pepper). Seeds albuminous.

Official drug	Part used	Botanical origin	Habitat
Belladonnæ Folia	Leaves	<i>Atropa Belladonna</i>	} Central and Southern Europe
Belladonnæ Radix	Root	<i>Atropa Belladonna</i>	
Stramonium	Leaves	<i>Datura Stramonium</i> and <i>D. Tatula</i>	} Asia and Tropical America
Hyoscyamus	Leaves and flower tops	<i>Hyoscyamus niger</i>	
Solanum N.F.	Ripe fruit	<i>Solanum carolinense</i>	United States
Capsicum	Fruit	<i>Capsicum frutescens</i>	Tropical America
Dulcamara N.F.	Twigs and stems	<i>Solanum Dulcamara</i>	Europe and Asia
<b>Unofficial</b>			
Duboisia	Leaves	<i>Duboisia myoporoides</i>	
Tabacum	Leaves	<i>Nicotiana tabacum</i>	Tropical America
Scopola	Rhizome	<i>Scopola Carniolica</i>	Alps and Carpathian Mts.
Manaca	Root	<i>Brunfelsia Hopeana</i>	Tropical America
Paprika	Fruit	<i>Capsicum annum</i> varieties	} America ? culti- vated
Pimiento	Fruit	Variety of <i>Capsicum</i> <i>annuum</i>	



FIG. 186.—Nightshade, or bittersweet (*Solanum Dulcamara*). (Gager.)

*Scrophulariaceæ* or *Figwort Family*.—Herbs (*Linaria*, *Verbascum*, *Gerardia*, *Digitalis*, etc.), shrubs (shrubby *Veronicas*, etc.), rarely trees (*Paulownia imperialis*). Stem, branches and leaves usually green and independently vegetating, but in *Pedicularis*, *Gerardia*, *Euphrasia*, *Buchnera*, *Rhinanthus*, etc., the stem, leaves, and branches are condensed from the development of a parasitic root habit. Stems cylindrical to frequently quadrangular, especially when leaves are opposite. Leaves alternate to opposite and decussate, simple, exstipulate, often hairy but becoming by drought or parasiticism reduced to scales or almost absorbed. Inflorescence a raceme of cymes (*Paulownia*) or a simple raceme (*Foxglove*, *Linaria*, etc.) or spike (*Verbascum Thapsus*) or, if leaves are opposite, often a whorl of axillary flowers or solitary axillary flowers. Flowers rarely regular, mostly irregular; calyx of five sepals condensed in *Veronica* to four through absorption of one sepal by fusion of two sepals; corolla of five to four petals, deeply synpetalous varying from rotate (*Verbascum Blattaria*, etc.) to irregular tubular to elongate, irregular bilabiate to funnel-shaped. In color corolla varies from greenish to greenish-yellow or white (*Scrophularia*) to pure white or from red to purple to blue (*Veronica*). Stamens five, fertile, equal in length in a few *Verbascum* species or unequal in other *Verbascum* species to stamens four with a long sterile staminode (*Pentstemon*) to four didynamous stamens with a short petaloid staminode (*Scrophularia*) to four didynamous stamens with a minute often nectariferous staminode (*Linaria*), to frequently four didynamous stamens only, the two lateral or two anterior stamens stronger and longer (*Antirrhinum*) to two perfect stamens and two minute staminodes (*Calceolaria*) to two stamens alone developed (*Veronica*). Pistil bicarpellate; ovary two-celled with central placentation; style terminal with bilobed stigma; ovules numerous, small. Fruit a two-celled and usually many-seeded capsule. Seeds richly albuminous, anatropous or amphitropous.

Official drug	Part used	Botanical origin	Habitat
Digitalis	Leaves	<i>Digitalis purpurea</i>	Europe
Leptandra N.F.	Rhizome and roots	<i>Veronica virginica</i>	United States and Canada





FIG. 187.—*Digitalis purpurea* var. *gloxinaefolia*.

Official drug	Part used	Botanical origin	Habitat							
Verbasci Flores N.F.	Corollas with stamens	<table border="0"> <tr> <td>{</td> <td>Verbascum phlomoides</td> <td>}</td> <td rowspan="2">Europe and Asia</td> </tr> <tr> <td>{</td> <td>Verbascum thapsiforme</td> <td>}</td> </tr> </table>	{	Verbascum phlomoides	}	Europe and Asia	{	Verbascum thapsiforme	}	
{	Verbascum phlomoides	}	Europe and Asia							
{	Verbascum thapsiforme	}								
Verbasci Folia N.F.	Leaves	<table border="0"> <tr> <td>{</td> <td>Verbascum Thapsus and other species of Verbascum</td> <td>}</td> <td rowspan="2">Europe and Asia</td> </tr> </table>	{	Verbascum Thapsus and other species of Verbascum	}	Europe and Asia				
{	Verbascum Thapsus and other species of Verbascum	}	Europe and Asia							

*Pedalinaceæ* or *Sesame Family*.—Tropical herbs often thickly covered with viscous hairs. Leaves soft, usually alternate, more rarely opposite, exstipulate. Flowers irregular, pentamerous. Fruit a capsule (*Sesamum*, etc.) drupe or rarely a one-seeded indehiscent nut. Seeds exalbuminous usually.

Official drug	Part used	Botanical origin	Habitat
Oleum Sesami	Fixed oil	Sesamum indicum (cultivated varieties)	Asia and Africa

*Acanthaceæ* or *Acanthus Family*.—Usually herbaceous (*Ruellia*), rarely sub-woody or woody plants, occasionally bushy in habit, containing cystoliths in the mesophyll or epidermal cells of the leaves and in the parenchyma of the roots and stems. Leaves opposite, more rarely whorled, entire, exstipulate. Inflorescence a raceme of condensed cymes becoming a simple raceme or spike, rarely condensed into a solitary terminal inflorescence. Flowers hermaphrodite, usually irregular; calyx five-cleft; corolla hypogynous, gamopetalous, more or less bilabiate, funnel-form and composed of five sepals; stamens usually four (*Ruellia*, etc.), occasionally reduced to two as in genus *Dianthera*, didynamous or diandrous, epipetalous; pistil bicarpellate; ovary two-celled, superior, with numerous campylotropal ovules; style terminal, filiform. Fruit a capsule containing numerous curved seeds. The family is of pharmaceutical interest mainly because of *Ruellia ciliosa*, a pubescent perennial herb growing in the Eastern United States, whose rhizome and roots have frequently been admixed with or substituted for *Spigelia*.

*Labiata* (*Lamiaceæ*) or *Mint Family*.—Herbs producing creeping runners that spread out and root at the nodes. Stems quadrangular, rarely cylindrical in outline. Leaves opposite, decussate, mainly petiolate; leaf margin nearly always serrate, dentate or crenate.

Stems and leaves further characterized by the presence of glandular hairs containing aromatic volatile oil. These hairs consist of a short one-celled stalk and a head (gland) of six or eight cells. Inflorescence a raceme or spike of verticillasters (double dichesial cymes) or, as in the Ground Ivy, a reduced verticillaster. Flowers typically



FIG. 188.—*Mentha piperita*—Flowering branch. (Sayre.)

pentamerous, rarely tetramerous; sepals five, synsepalous, ribbed and forming a tubular regular or irregular bilabiate (Scull cap, etc.) calyx whose upper lip is bifid and lower trifid; corolla of five to four gamopetalous petals, hypogynous, frequently two-lipped, the upper lip bifid, the lower trifid; stamens four, didynamous, rarely one pair alone fertile and the other pair reduced in some cases almost or

quite to disappearing point (*Salvia* and *Monarda*); pistil bicarpellate, embryologically two-celled with two ovules in each cavity, becoming at time of flowering four-celled with one ovule in each cavity. Style embryologically terminal but, upon opening of flower, deeply gynobasic, elongate, slender with two stigmatic surfaces. Fruit four nutlets enclosing as many exalbuminous seeds.

Official drug	Part used	Botanical origin	Habitat
Mentha Piperita	Leaves and flowering tops	Mentha piperita	Europe
Mentha Viridis	Leaves and flowering tops	Mentha spicata	Europe
Scutellaria N.F.	Entire plant	Scutellaria lateriflora	United States and Canada
Oleum Thymi	Volatile oil from flowering plant	Thymus vulgaris	Southern Europe
Oleum Rosmarini	Volatile oil from fresh flowering tops	Rosmarinus officinalis	Mediterranean Basin
Oleum Lavendulae	Volatile oil from fresh flowering tops	Lavendula vera	Southern Europe
Cataria N.F.	Leaves and flowering tops	Nepeta Cataria	Europe and Asia
<b>Unofficial</b>			
Salvia	Leaves	Salvia officinalis	Southern Europe
Marrubium	Leaves and flowering tops	Marrubium vulgare	Europe and Asia
Hedeoma	Leaves and flowering tops	Hedeoma pulegioides	United States and Canada
Herba Majoranae	Leaves and flowering tops	Origanum Majorana	Mediterranean regions
Collinsonia	Rhizome and roots	Collinsonia canadense	United States
Serphyllum	Leaves and flowering tops	Thymus Serphyllum	Europe and Asia
Melissa	Leaves and flowering tops	Melissa officinalis	Southern Europe, Asia Minor
Monarda	Leaves and flowering tops	Monarda punctata	United States
Origanum	Leaves and flowering tops	Origanum vulgare	Europe, Asia and North Africa
Hyssopus	Leaves and flowering tops	Hyssopus officinalis	Southern Europe

*Verbenaceæ* or *Verbena* Family.—Herbs (*Verbena* sps.), shrubs (*Clarodendron*), occasionally trees (Black Mangrove of Florida) having characters which averagely agree with the *Labiata*. They are distinguished from the *Labiata* mainly by being rarely scented, by their flowers having five stamens and a terminal style, by their fruits being either drupes or berries and by the fact that their seeds while being typically exalbuminous, yet occasionally are slightly albuminous.

Official drug	Part used	Botanical origin	Habitat
Verbena N.F.	Overground portion in flower	<i>Verbena hastata</i>	United States

**V. Order Rubiales.**—*Rubiaceæ* or *Madder* Family.—Herbs (*Galium*, *Mitchella*, etc.), shrubs (*Cephalanthus*, etc.), or trees (*Cinchona* species) with fibrous roots, sometimes, as in *Cephaelis Ipecacuanha*, annularly enlarged. Roots, stems and to a less extent leaves rich in varied alkaloids, some of medicinal value. Leaves opposite, entire, stipulate and interpetiolate. Inflorescence a raceme of dicesial cymes occasionally condensing to scorpioids. Flowers perfect, often dimorphic, pentamerous or tetramerous; sepals five (*Cinchona*, etc.) but four in *Galium*, small, green, subtended with other flowers by one or two or more enlarged petaloid bracts; petals five (*Cinchona*, etc.) to four in *Galium*, stellate, varying from shallow rotate to elongate tubular or funnel-shaped with stellate limbs; stamens five to four, epipetalous; pistil nearly always bicarpellate, rarely of five to four carpels; ovary inferior, two-celled with central placentation; styles either distinct with knob-shaped stigmas or style elongate, filiform ending in bilobed stigmas. Fruit varied, a capsule in *Cinchona*, a berry in *Coffee*, a drupe, or frequently as in *Galium* dry and splitting into nutlets; seeds albuminous, each with a curved embryo.

Official drug	Part used	Botanical origin	Habitat
Caffeina	Feebly basic principle	<i>Coffea arabica</i>	Eastern Africa
Cinchona	Bark	{ <i>Cinchona Ledgeriana</i> , <i>C. Calisaya</i> and hybrids of these with other <i>Cinchona</i> species	South America

Official drug	Part used	Botanical origin	Habitat
Cinchona Rubra	Bark	{ Cinchona succirubra or its hybrids	} South America
Coffea Tosta N.F.	Roasted seeds	{ Coffea arabica Coffea liberica	
Gambir	{ Prepared ex- tract from de- coctions of leaves and twigs	} Ourouparia	} Gambir East Indies
Ipecacuanha	Root		
			} Brazil } United States of } Columbia



FIG. 189 —*Cephaëlis ipecacuanha*—Plant and dried root. (Sayre.)

*Caprifoliaceæ* or *Honey Suckle Family*.—Shrubs or rarely herbs. Leaves entire, opposite, exstipulate or with delicate, attenuate or filiform stipules. Inflorescence varying from a raceme of shortened cymes to a capitulum. Flowers varying from regular and small (*Sambucus*, *Viburnum*, etc.) to increasingly large, slightly irregular and ultimately very irregular in some *Loniceras* and in a few *Weigelas* and allies; calyx pentamerous, superior; corolla superior, gamopetalous, limb pentafid, small, in *Viburnum* and *Sambucus* to elongate, tubular or irregular infundibuliform in *Loniceras*; stamens five, inserted on tube of corolla and alternating with corolla segments; filaments equal or didynamous (in irregular flowers); ovary inferior, rarely five- to three-celled, usually three- or frequently two-celled; style terminal. Fruit a berry (*Viburnum*) from an inferior ovary, several celled, occasionally becoming one-celled with several to rarely one seed, or fruit a capsule (*Diervilla*, *Weigelia*). Seeds albuminous.

Official drug	Part used	Botanical origin	Habitat
Sambucus N.F.	Flowers	{ <i>Sambucus canadensis</i> }	United States
		{ <i>Sambucus nigra</i> }	Europe
Viburnum Prunifolium	Bark	{ <i>Viburnum</i>	Eastern and central United States
		{ <i>prunifolium</i>	
Viburnum Opulus N.F.	Bark	{ <i>Viburnum Lentago</i>	United States and Canada
		{ <i>Viburnum Opulus</i> var. <i>Americanum</i>	

**VI. Order Campanulales.**—*Cucurbitaceæ* or *Gourd Family*.—Herbaceous, very often annual (*Colocynth*, etc.), more rarely perennial (*Bryonia*, etc.), sometimes shrubby plants, the perennial and shrubby forms perennating by swollen roots some of which are heavy and tuberous. Stems very usually grooved and ridged, often provided with roughened and barbed hairs. Tendrils are frequently produced in the axils of leaves from tendril axillary buds (Pumpkin, *Colocynth*, Watermelon, Cucumber, Bryony, etc.). Leaves varying from entire, simple, usually deltoid to triangular through stages of trilobate, pentalobate, deeply palmatifid to palmatipartite to seldom approaching compound (*Colocynth*). Venation in nearly all cases palmate. Leaves thin, herbaceous, much expanded, often hairy. Vascular bundles of petioles, branches and stems, bicollateral. Inflo-

rescence either of loose cymes or more frequently of racemes or spikes or entire axillary inflorescence may become solitary axillary. Flowers pentamerous, very rarely tetramerous, monœcious (*Bryonia alba*) or diœcious (*Bryonia dioica*); sepals five, gamosepalous, adnate to ovary; corolla of five, rarely four gamopetalous petals varying in size and shape from small to large campanulate or broadly cup-shaped (Cucumber) and in color from greenish-yellow to greenish white to pure yellow to yellowish-white to white; stamens typically five, epigynous, with anthers either joined by pairs or synantherous; carpels usually three; ovary inferior, one- to three-celled. Fruit a pepo (a berry from an inferior ovary with thick skin). Seeds flat and exalbuminous.



FIG. 190.—Colocynthis—Portion of vine and whole fruit. (*Sayre.*)

Official drug	Part used	Botanical origin	Habitat
Bryonia N.F.	Root	{ <i>Bryonia alba</i> <i>Bryonia dioica</i> }	Europe
Colocynthis	Pulp of fruit	<i>Citrullus Colocynthis</i>	Africa and Asia
Pepo	Seeds	<i>Cucurbita Pepo</i> (cultivated varieties)	Tropics
Elaterium	Principle from elaterium	<i>Ecballium Elaterium</i>	Mediterranean region
<b>Unofficial</b>			
Watermelon Seed	Seeds	<i>Citrullus vulgaris</i>	Southern Asia
Momordica (Balsam apple)	Fruit	<i>Momordica</i> <i>Balsamina</i>	East Indies

*Campanulaceæ* or *Bluebell Family*.—Herbs of annual or more commonly perennial growth rarely sub-shrubby or sub-woody in habit, frequently with laticiferous tubes containing a milky juice. Stem upright or feeble and spreading. Leaves alternate, simple, exstipule-



late. Inflorescence primitively a racemose cyme condensing into a raceme, to a sub-capitulum and ultimately to a capitulum. Flowers regular, campanulate to campanulate-elongate to elongate and deeply cleft in petals; sepals five, only slightly synsepalous, epigynous; petals five, campanulate to campanulate-tubular to tubular elongate to tubular and deeply cleft; corolla varying in color from greenish-yellow to yellowish-white to white or again, from yellowish-purple (rarely through yellowish-pink or red) to purple to pure blue; stamens five, epigynous, usually free from corolla; nectary epigynous; pistil usually tricarpellary; ovary as many celled as number of carpels and with central placenta; style single elongate; stigmas as many as carpels. Fruit a capsule. Seeds albuminous. The plants contain inulin.

*Lobeliaceæ* or *Lobelia Family*.—Herbs, with inulin and latex contents, corresponding with *Campanulaceæ* in their vegetative parts, but differing from that group by having irregular flowers (pale blue in *Lobelia inflata*), anthers always synantherous and pistil always bicarpellate with two-celled ovary and bilobed or bilabiate stigma.

Official drug	Part used	Botanical origin	Habitat
Lobelia	Leaves and flowering tops	<i>Lobelia inflata</i>	United States and Canada

VII. Order *Aggregatæ*.—*Valerianaceæ* or *Valerian Family*.—Herbaceous often low succulent plants with creeping rhizomes, frequently strongly scented and possessing stimulating properties. Leaves frequently dimorphic; radical fascicled; cauline opposite; petiole dilated, exstipulate. Inflorescence a raceme of dicesial or scorpioid cymes. Flowers more or less irregular; calyx absent as such but represented by a series of teeth that are incurved in the bud and flower and which expand later into a pappose crown and act in the fruit as a pappose disseminator; corolla pentamerous, gamopetalous, varying from rotate synpetalous to irregular tubular with petals diversely united, in color varying from greenish-white to white or pink (*Valeriana officinalis*) to crimson; stamens three to two or one (*Valerian*), epipetalous; pistil syncarpous; ovary usually one-celled inferior; style filiform with three stigmatic surfaces.



FIG. 191 —*Valeriana officinalis*—Plant and rhizome. (Sayre.)

Fruit an akene from inferior ovary crowned by a persistent expanded pappose calyx rudiment. Seeds anatropous, exalbuminous.

Official drug	Part used	Botanical origin	Habitat
Valeriana	Rhizome and roots	<i>Valeriana officinalis</i>	Europe and Asia

*Compositæ (Asteraceæ) or Daisy Family.*—Herbs, rarely shrubs or trees, of annual or perennial habit, and with watery or milky juice.

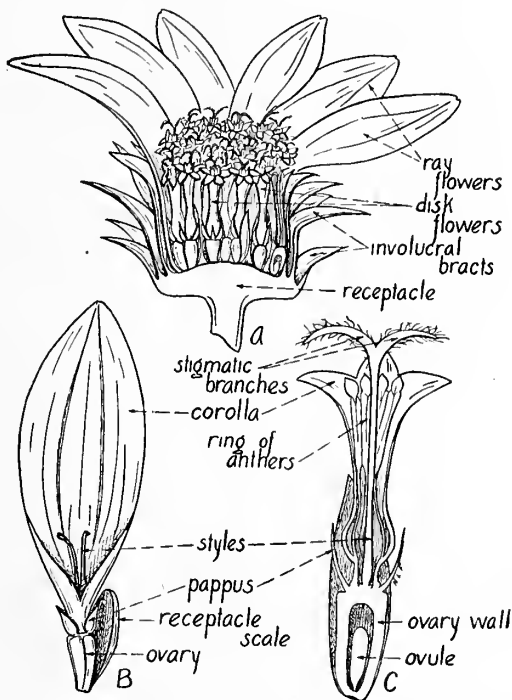


FIG. 192.—Capitulum of a composite Jerusalem artichoke (*Helianthus tuberosus*). A, lengthwise section of capitulum,  $\times 1$ ; B, ray flower,  $\times 6$ ; C, disk flower, cut lengthwise,  $\times 6$ . (A after Baillon, B and C, Robbins.)

Inulin is present in cell sap of parenchyma. Leaves alternate, rarely opposite, simple to compound, exstipulate. Inflorescence a capitulum or a raceme of capitula, each capitulum surrounded by an in-

volucre or protective whorl of bracts, and composed of numerous florets that may be: (a) wholly regular, tubular and hermaphrodite (Thistle, etc.); or (b) central florets as in (a), but marginals strap-



FIG. 193.—*Matricaria chamomilla*—Branch and dissected flowers. (Sayre.)

shaped or ligulate and usually pistillate (Daisy, Dahlia, etc.); or (c) florets all ligulate and hermaphrodite (Dandelion, Chicory, etc.); or (d) florets in part or in whole bilabiate (Mutisia, etc.). Flowers small (florets) closely crowded, pentamerous, shaped as above, with

ovary inferior and other floral parts superior. Sepals rudimentary tooth-like (Sunflower), or reduced to a pappose or hairy rudiment above ovary that is functionless during flowering, but that expands in fruit as a hairy fruit disseminator (Dandelion, Thistle, etc.); or sepals wholly absorbed (Daisy). Petals synpetalous, tubular, ligulate or rarely bilabiate, greenish-yellow to white, or through pink-crimson and purple to blue (chicory). Stamens five, epipetalous, filaments distinct, anthers united into an upright anther-box (so synantherous) into which pollen is shed before or during opening of each floret. Carpels two, syncarpous, ovary inferior, one-celled with single ovule; style simple, at first short, later elongating and by collecting hairs sweeping pollen to top of anther box, then dividing into two stigmatic surfaces with stigmatic hairs for pollen reception. Fruit an indehiscent achene often (Dandelion, Thistle) crowned by the pappose, calyx rudiment. Seed single, exalbuminous.

Official drug	Part used	Botanical origin	Habitat
Lactucarium	Dried milk juice	<i>Lactuca virosa</i>	Europe
Arnica	Flower heads	<i>Arnica montana</i>	Europe and northern Asia
Matricaria	Flower heads	<i>Matricaria</i> <i>Chamomilla</i>	Europe and western Asia
Calendula N.F.	Ligulate florets	<i>Calendula officinalis</i>	Mediterranean basin
Senecio N.F.	Overground parts	<i>Senecio aureus</i>	United States
Absinthium N.F.	Leaves and flowering tops	<i>Artemisia</i> <i>Absinthium</i>	United States and Canada
Eupatorium N.F.	Leaves and flowering tops	<i>Eupatorium</i> <i>perfoliatum</i>	North America
Grindelia	Leaves and flowering tops	{ <i>Grindelia camporum</i> <i>Grindelia cuneifolia</i> <i>Grindelia squarrosa</i> }	{ Western North America }
Inula N.F.	Rhizome and roots	<i>Inula Helenium</i>	Europe and Asia
Taraxacum	Rhizome and roots	<i>Taraxacum officinale</i>	Europe and Asia
Echinacea N.F.	Rhizome and roots	<i>Brauneria pallida</i>	Central United States
Pyrethrum	Root	<i>Anacyclus Pyrethrum</i>	Northern Africa and southern Europe

Official drug	Part used	Botanical origin	Habitat
Lappa N.F.	Root	Arctium Lappa and other species of Arctium	Europe and northern Asia
Farfara N.F.	Leaves	Tussilago Farfara	Europe
Santoninum	Inner anhydride of santonin acid	Artemisia pauciflora	Russian Turkestan
<b>Unofficial</b>			
Anthemis	Flower heads	Anthemis nobilis	Europe
Pyrethri Flores	Flower heads (unexpanded or partly expanded)	Chrysanthemum cinerariifolium	Dalmatia
		Chrysanthemum roseum	Herzegovina
		Chrysanthemum Marschallii	Western Asia



FIG. 194.—Chicory (*Cichorium Intybus*). *A*, portion of flowering branch; *B*, basal leaf (runcinate-pinnatifid); *C*, median longitudinal section through a head, showing the insertion of the flowers; *D*, individual flower; *E*, fruit (ripened ovary), showing the persistent pappus (calyx) of short scales. (*Gager.*)

<b>Official drug</b>	<b>Part used</b>	<b>Botanical origin</b>	<b>Habitat</b>
Santonica	Unexpanded flower heads	<i>Artemisia pauciflora</i>	Russian Turkestan
Carthamus	Tubular florets	<i>Carthamus tinctorius</i>	India
Achillea	Leaves and flowering tops	<i>Achillea millefolium</i>	Europe and Asia
Tanacetum	Leaves and flowering tops	<i>Tanacetum vulgare</i>	Europe
Gnaphalium	Leaves and flowering tops	<i>Gnaphalium</i> <i>polycephalum</i>	North America
Cichorium	Rhizome and roots	<i>Cichorium Intybus</i>	Europe
Oleum Erigerontis	Volatile oil	<i>Erigeron canadensis</i>	North America

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